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A STUDY OF NEARSHORE MARINE AND BEACH ECOLOGY, PACIFIC MISSILE --ETC(U)
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A STUDY OF NEARSHORE MARINE AND BEACH ECOLOGY, PACIFIC MISSILE RANGE FACILITY, KAUAI, HAWAII

MARCH 1977

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DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20373

ABSTRACT

The Naval Oceanographic Office, at the request of the Pacific Missile Range, initiated an environmental impact study of the effects of cable laying operations at the Pacific Missile Range Facility, Barking Sands, Kauai, Hawaii. The initial field investigation was conducted during July 1974.

Beach morphology and ecology are described, and vegetation zones were identified and charted. Beach profiles were measured and marked for future resurvey. Intertidal and nearshore biological communities were identified, and their distribution and densities were documented. Two permanent ecological monitoring stations (quadrats) were established to provide a means of determining changes in the coral reef populations. Three current meters were installed at locations selected by the Pacific Missile Range to assist in cable route engineering studies.

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A STUDY OF NEARSHORE MARINE AND BEACH ECOLOGY, PACIFIC MISSILE RANGE FACILITY, KAUAI, HAWAII.

(10) Howard D. Huddell
J. Craig Willett

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FOREWORD

In response to a request from the Pacific Missile Range, the Naval Oceanographic Office conducted an environmental - ecological survey at the Pacific Missile Range Facility, Kauai, Hawaii during July and August 1974. This report contains the results of that investigation. The ecological study provides a basis for monitoring the coral reef habitat for any changes caused by man or nature.

J. E. AYRES
Captain, USN
Commander

ACKNOWLEDGEMENTS

The field work for this study could not have been accomplished without the outstanding support received from the Pacific Missile Range Facility at Kauai. Particularly helpful were LCDR Hopkinson of the Operations Office and the men of the marine department who provided boat support for the deep zone studies and current meter installations.

In addition to the authors, the field team included the following NAVOCEANO personnel: Peter Bockman, who was responsible for the photographic documentation; John A. Bunce, who identified intertidal and shallow zone algae and fish; and Richard C. Wright, who identified intertidal mollusks and echinoderms.

Terrestrial plant specimens were identified by Dr. Derral Herbst of the Pacific Tropical Botanical Garden at Koloa, Kauai.

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I. INTRODUCTION

At the request of the Pacific Missile Range, the Naval Oceanographic Office initiated a study of beach and shallow water ecology at the Pacific Missile Range Facility at Barking Sands, Kauai, Hawaii. The purpose of the study is to determine the environmental impact upon the beach and coral reef of cable laying operations for the Barking Sands Underwater Range.

A three-phase study was planned to: (1) establish an ecological baseline for the marine and beach communities, (2) monitor changes in the marine communities and beach morphology as they are related to specific activities of the Pacific Missile Range Facility, and (3) provide environmental information to the Pacific Missile Range to assist in preventing or minimizing ecological damage.

II. PREVIOUS INVESTIGATIONS

The shallow-water environment off Barking Sands was investigated by the Naval Oceanographic Office (Ruggles, 1964) and by the Hawaii Institute of Geophysics (Chamberlain, 1965) prior to cable laying at Barking Sands. Both investigations collected geological data to assist in finding the most practical cable route.

From 1966 through 1968, the Army Corps of Engineers (1964, 1969) conducted a study of beach and nearshore sedimentary processes to ascertain the feasibility of constructing a small-boat harbor near Barking Sands. Beach and nearshore sedimentary processes in the Barking Sands area were also studied by Inman et al. (1963), and Chamberlain (1968). The beachrock of the area was described by Emery and Cox (1956).

Nearshore currents off Nohili Point were briefly studied and described by Laevastu et al. (1964) who tracked three drogues during July 1963.

No published data could be found on the marine flora and fauna of the west coast of Kauai; however, considerable work exists on other coral reef areas in the Hawaiian Islands. An annotated bibliography of most of these publications appears in Gordon and Helfrich (1970).

III. METHODS AND PROCEDURES

The initial field investigation for this study was conducted from 7 July through 5 August 1974. The general objectives of this investigation were to collect data on the beach and nearshore communities to establish an ecological baseline, provide a means for future monitoring of the ecology, and collect current data to assist in engineering studies of the cable route and type of installation.

A. Beach Morphology and Ecology

Beach morphology was studied by measuring beach profiles and mapping the distribution of sand, beachrock, and vegetated areas.

Eleven reference points were established on the coastline (fig. 1) to provide horizontal control for the beach surveys and for bathymetric and ecological transects. Each point was marked by a steel stake designated by a letter stamped on the side of the stake. The position of each reference stake was determined with a theodolite and surveyor's steel tape.

Beach profiles were measured at reference stakes A, B, C, D, F, H, I, J, and K. Standard leveling procedures were used. Elevations were measured at 10-foot (3 m) intervals along each profile utilizing a marked wire laid over the beach from the vegetation zone to the waterline. Profiles were measured perpendicular to the beach, and the repeatability of each profile was assured by referencing profile angles to prominent landmarks. Profile elevations were tied to a permanent bench mark, SANDIA-2, which has a known elevation with respect to mean low water.

Distributions and types of vegetation stabilizing the backshore zone were charted. Plant specimens were identified by the Pacific Tropical Botanical Garden. Color photographs were taken to further document ecological and morphological conditions on the beach.

B. Shallow and Intertidal Zones

Underwater ecological investigations were divided into intertidal, shallow, and deep zones based on depth and distance from shore. The shallow zone extended from the subtidal depth to 15-20 feet (4.6-6.1 m) deep, an area which could be conveniently surveyed from the beach without using a boat and shallow enough to investigate without scuba equipment.

Marine communities of the shallow zone were identified and charted using line transects, square-meter counts, and photographic documentation.

Line transects in the shallow zone were run normal to the shoreline from reference stakes A, B, E, F, G, H, I, and K. Coral colonies under each line were identified and tabulated along the entire transect. Bottom topography, substrate, and depth changes were described along each transect. At 100-foot (30.5 m) intervals a one-meter-square frame was placed on the bottom, and all organisms within the frame were counted and photographed. Algae, which frequently covered large areas, were not counted individually, rather coverage was estimated as an areal percentage of each species within the frame. Fish population counts were also made at each 100-foot interval; numbers of individuals within 15 feet (4.6 m) of the frame were tabulated by family.

Studies of the intertidal zone included visual observations and qualitative descriptions as well as several square-meter counts.

C. Deep Zone

Bathymetry was measured with a portable recording depth sounder between the 110-foot (33.5 m) depth and the shoreline. Eleven lines were run employing the beach reference stakes as controls. For each line a transit was set up over the reference stake, and the survey boat was guided by radio directions along a magnetic azimuth of 95°. Two-minute fixes along the line were provided by a theodolite operator equipped with a radio.

Line transects were run along the bottom in the deep zone from depths of 80 feet (24.4 m) to about 30 feet (9.1 m), and from 50 feet (15.2 m) to about 20 feet (6.1 m). Each transect was about 2,000 feet (610 m) long. Divers followed a cotton string which had been laid along the bottom from a small boat. The string was laid on a magnetic azimuth of 95° toward each beach reference stake from a buoy placed at the end of each line during the bathymetry operations. The bottom along each line was described and photographed with still and movie cameras. Close-up color photographs were taken of selected individual organisms or groups of organisms to provide qualitative documentation. Every coral or sponge along each transect was identified and tallied. Fish population estimates were made along selected transects. All fish within 15 feet (4.6 m) of each transect were counted and tabulated by family.

In addition to the transects surveyed by free-swimming divers, two were run by divers on a towed planeboard. One transect followed a course which crossed all the lines run previously, thereby providing a check of bottom conditions between lines. Positions of line transects in the deep zone are shown in figure 1.

D. Quadrats

Two permanent quadrats were established in water depths of about 45 and 30 feet (15.2 and 9.1 m) in areas of concentrated coral growth. Permanent quadrats provide a means of monitoring coral reef communities, that is, individual colonies can be observed and their condition documented during repeated surveys.

Each quadrat was 5 meters (16.4 ft) square, divided into nine equal squares by a temporary wire grid, and permanently marked at the corners by concrete blocks.

The major attached organisms within each quadrat were identified and charted on underwater slates (fig. 17). Using underwater photogrammetric techniques, an entire quadrat was photographed, and a photomosaic constructed. From the underwater chart and the photomosaic, a chart was constructed for each quadrat to show distribution and types of bottom organisms. In addition, various individual organisms within each quadrat were selected for closeup photographic documentation.

E. Current Measurements

Three current meters were installed on bottom mounts at locations selected by the Pacific Missile Range to assist in cable engineering studies.

These meters have a Savonius rotor for speed sensing and a vane for direction sensing. Speed and direction, sampled for 50-second periods at 15-minute intervals, are automatically coded on photographic film within the meter. Machine decoding and computer processing provided graphic displays of all data collected during the survey. Machine plots included current speed and direction histograms and frame number versus speed and direction. Progressive vector diagrams were constructed for selected data segments.

IV. RESULTS

A. Beach Morphology and Ecology

The beach within the study area is dominated by a resistant beachrock formation, which forms a ridge or platform extending 50 to 100 feet (15 to 30 m) onshore from the waterline. Inland of this beachrock is a band of loose sand with frequent blocks of eroded beachrock. As the lower layers of beachrock tend to be less cemented than the upper ones, undercutting characteristically creates large slabs of isolated rock (Emery and Cox, 1956).

The distribution of beachrock and sand and the measured profiles are shown in figures 2 through 9. The beachrock formation is most prominent in the vicinity of reference stakes H and I and dwindles in size toward the south. At reference stake A, the beach is almost entirely composed of sand, with beachrock appearing only below the low tide level. North of the study area is the Polihale beach, which contains the largest reservoir of beach sand in the State of Hawaii (Chamberlain, 1968).

The beach at Polihale appears to be prograding, while south of Nohili Point the coastline has retreated (Emery and Cox, 1956). The presence of the massive outcrops of beachrock and the steep scarp between reference stakes C and G are evidence of recent general erosion of the coast.

Between stakes C and D, a 100-foot (30.5 m) section of the beachrock has been removed for the Nohili drainage ditch (see fig. 10). Breaching of this section of beachrock has caused accelerated erosion of the coastline to 600 feet (183 m) on either side of the ditch and has created a trough behind the beachrock formation. Profiles D, F, and H (figs. 5, 6, and 7) show this trough and the steep scarp which has formed adjacent to it. A trough also exists behind the beachrock at profile K (fig. 9).

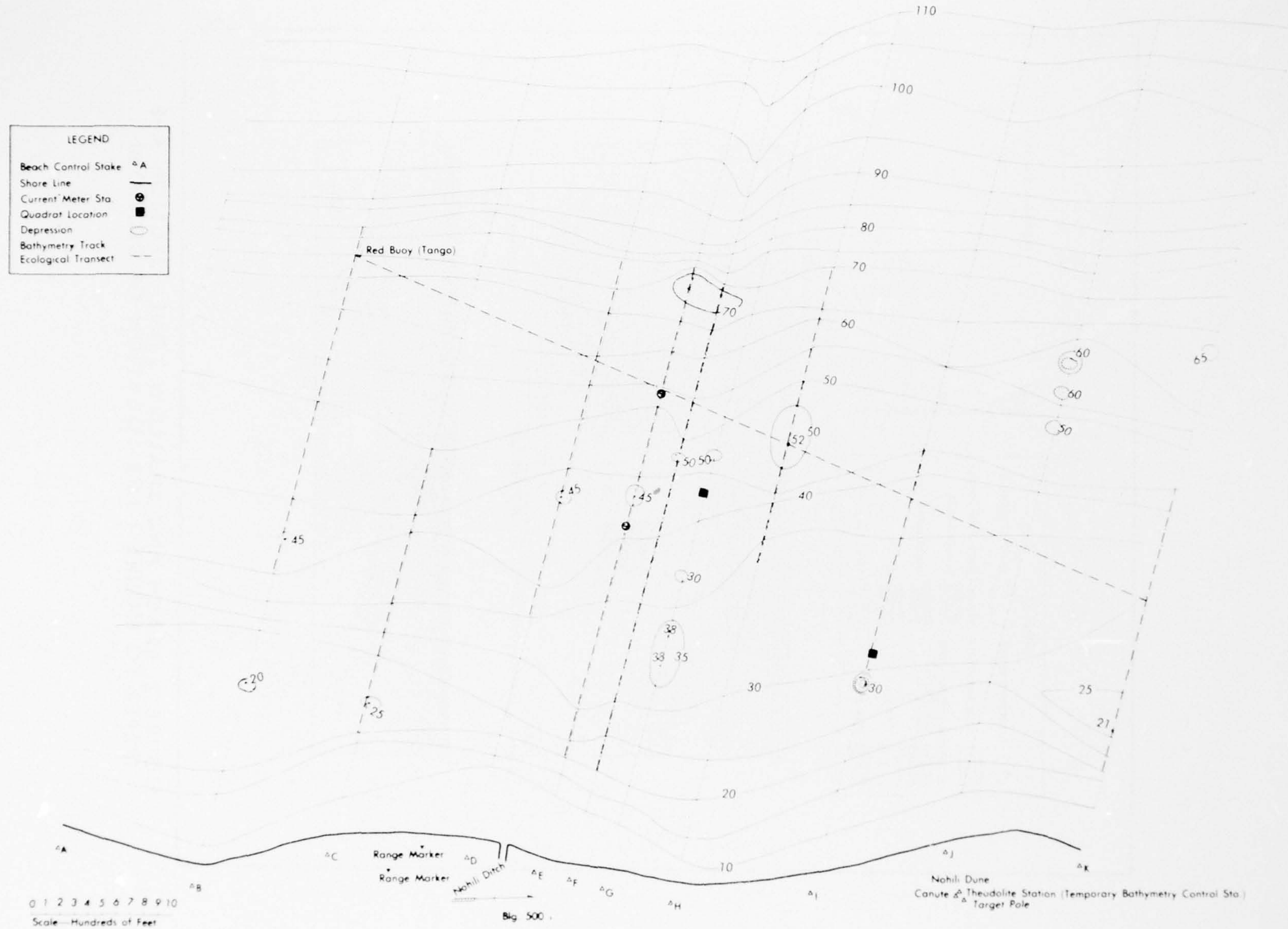


FIGURE 1. BATHYMETRY OF BARKING SANDS NEARSHORE AREA AND LOCATIONS OF DEEP ZONE ECOLOGICAL TRANSECTS

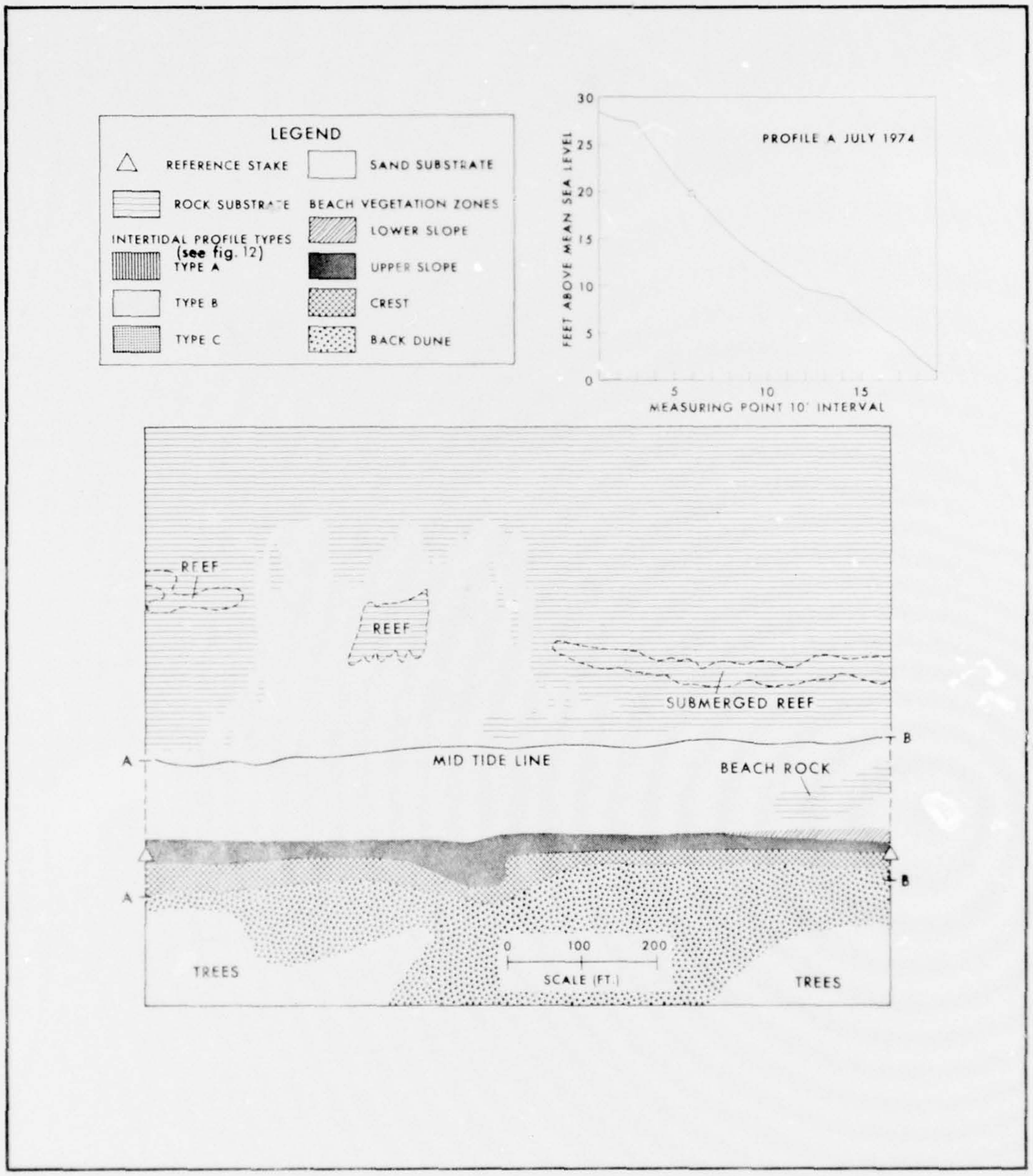


FIGURE 2. BEACH AND SHALLOW ZONE, SECTION A-B (REFER TO FIGURE 1 FOR LOCATION OF SECTION).

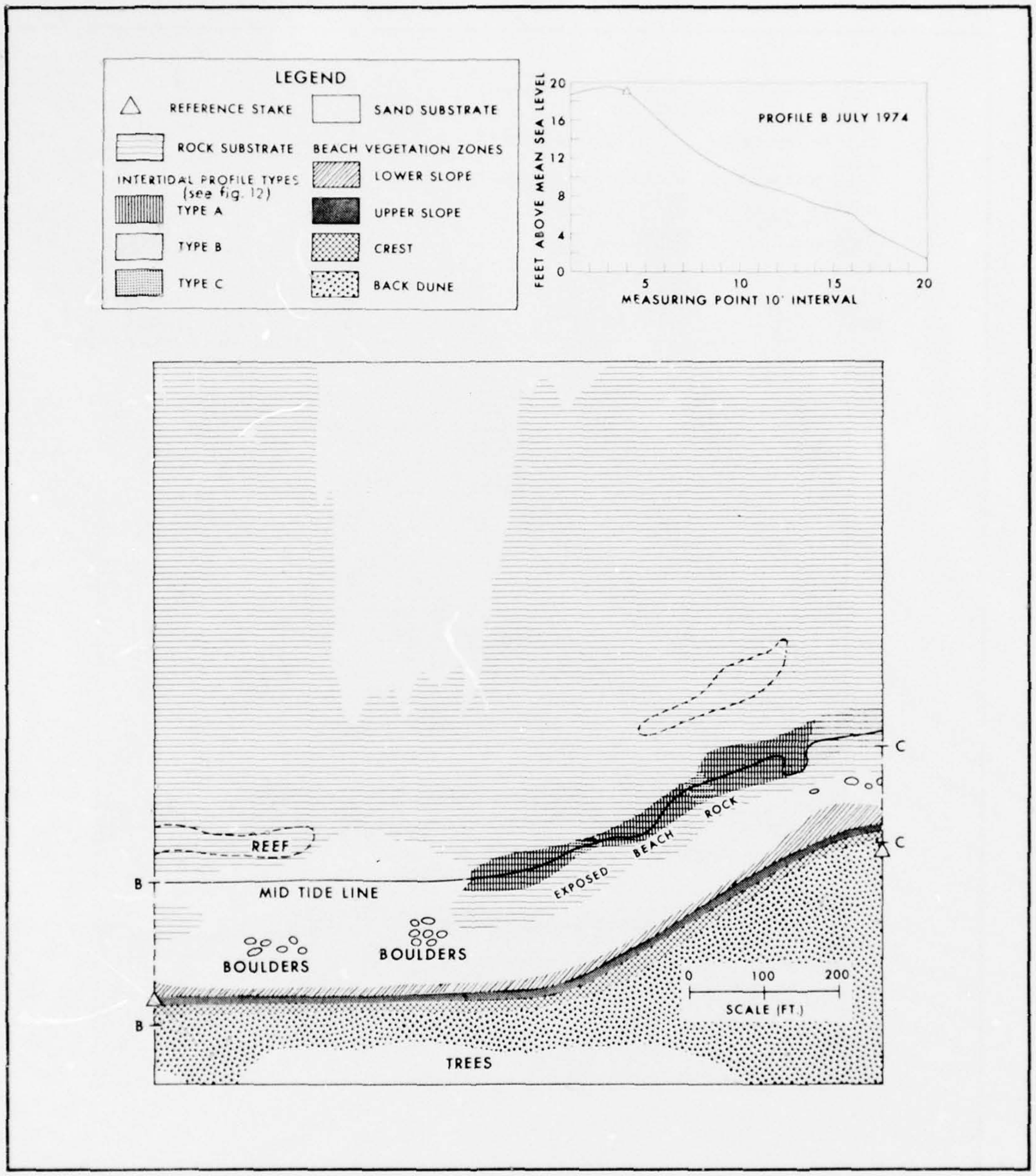


FIGURE 3. BEACH AND SHALLOW ZONE, SECTION B-C (REFER TO FIGURE 1 FOR LOCATION OF SECTION).

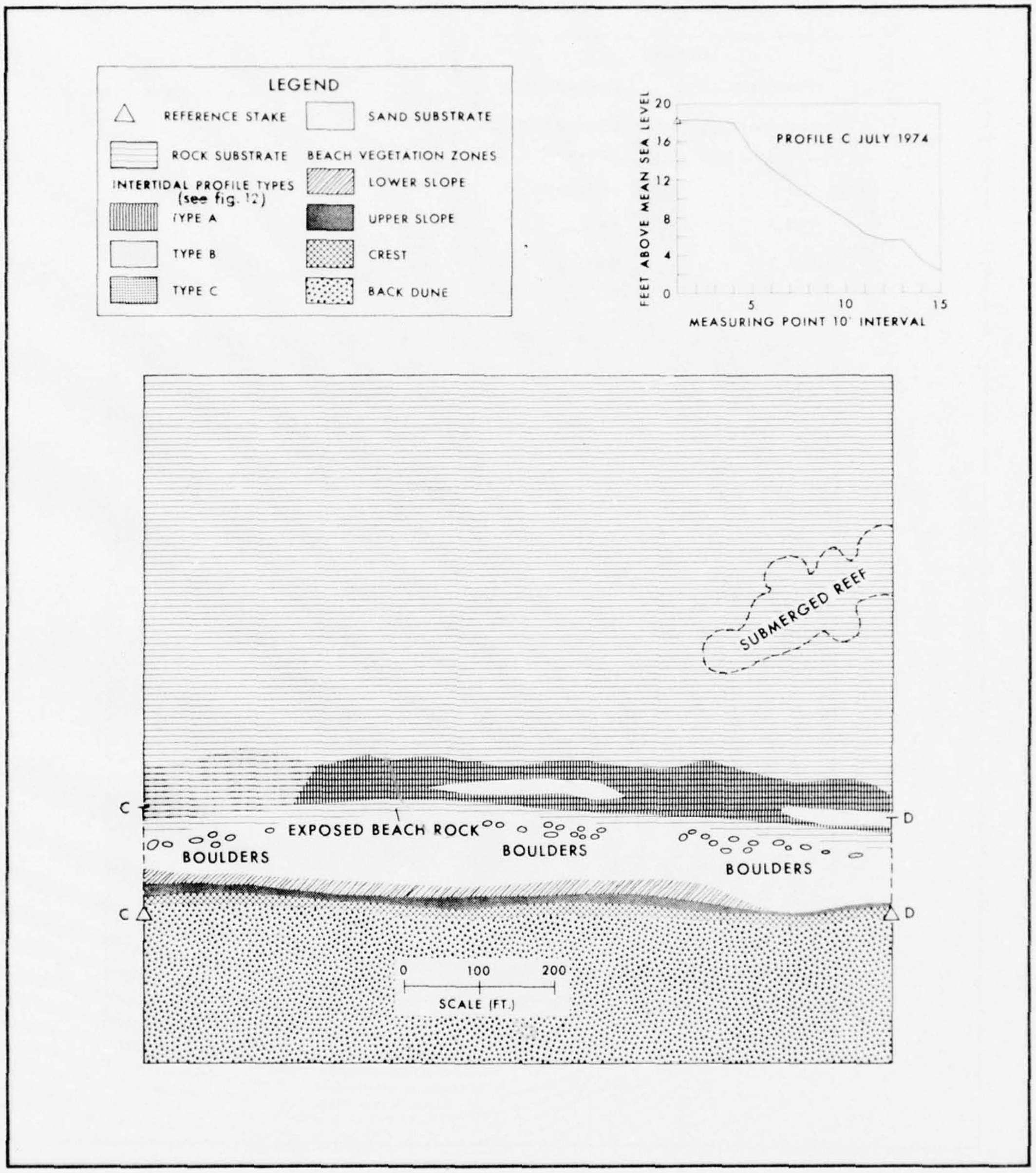


FIGURE 4. BEACH AND SHALLOW ZONE, SECTION C–D (REFER TO FIGURE 1 FOR LOCATION OF SECTION).

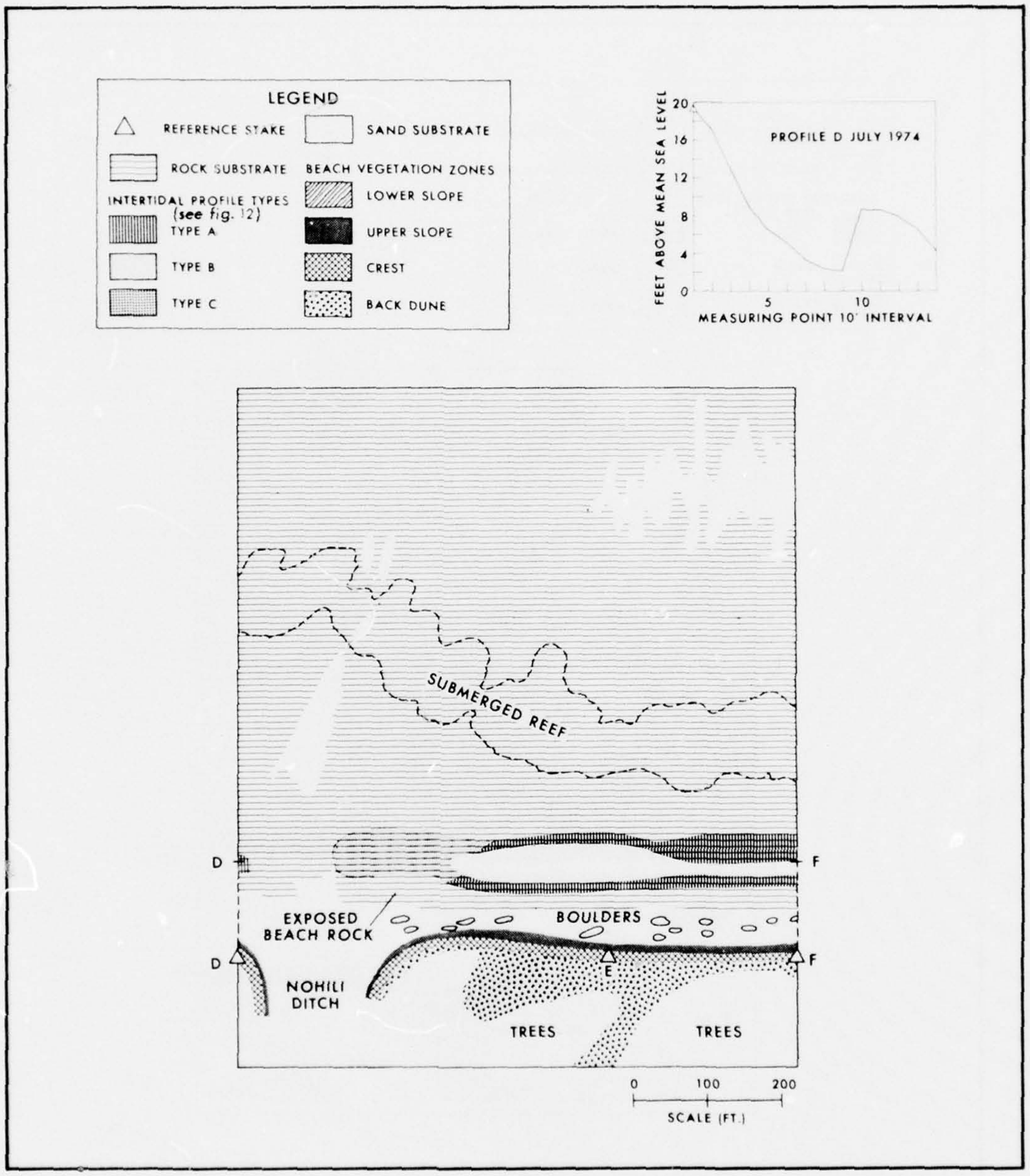


FIGURE 5. BEACH AND SHALLOW ZONE, SECTION D-F (REFER TO FIGURE 1 FOR LOCATION OF SECTION).

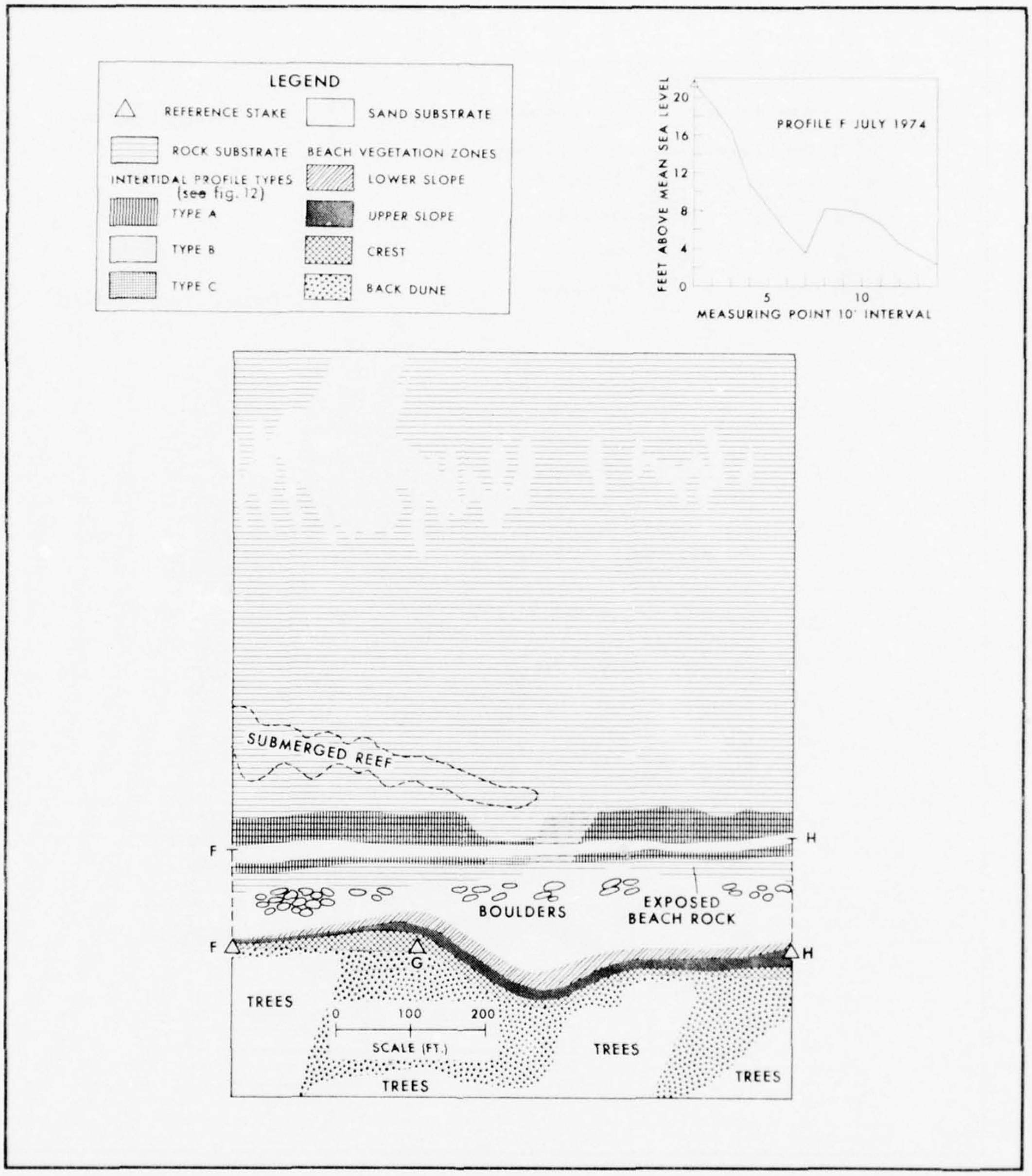


FIGURE 6. BEACH AND SHALLOW ZONE, SECTION F-H (REFER TO FIGURE 1 FOR LOCATION OF SECTION).

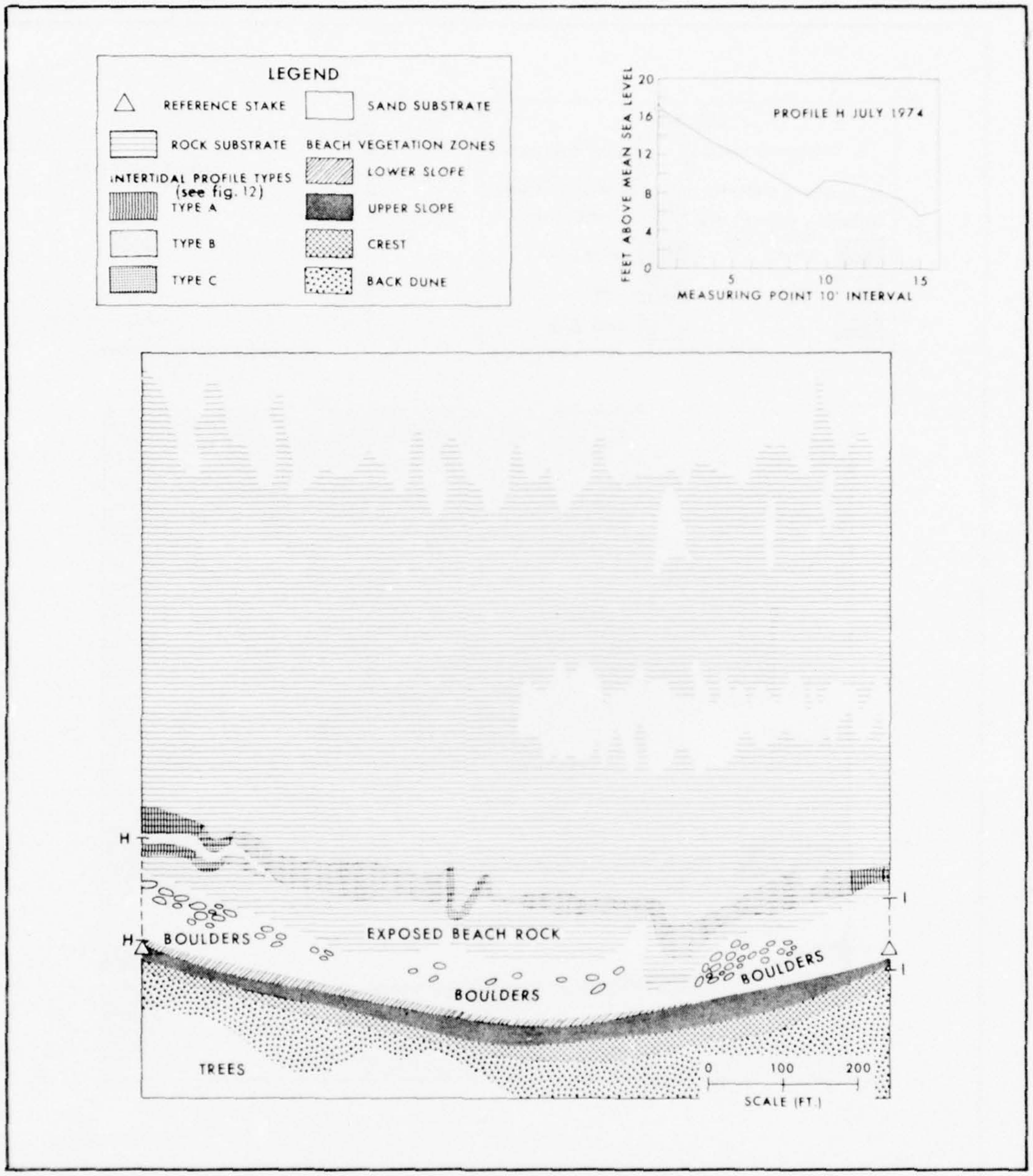


FIGURE 7. BEACH AND SHALLOW ZONE, SECTION H-I (REFER TO FIGURE 1 FOR LOCATION OF SECTION).

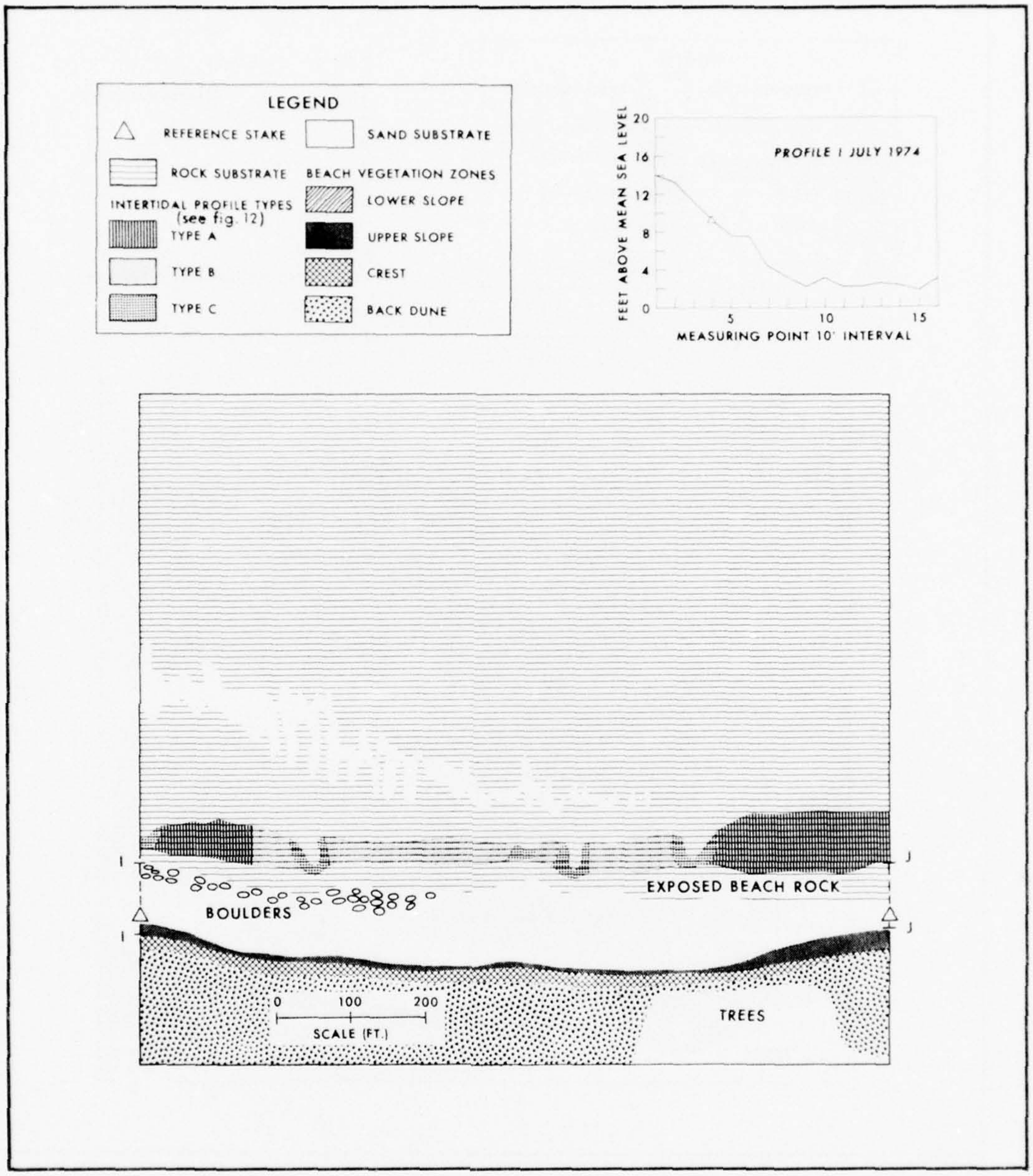


FIGURE 8. BEACH AND SHALLOW ZONE, SECTION I-J (REFER TO FGURE 1 FOR LOCATION OF SECTION).

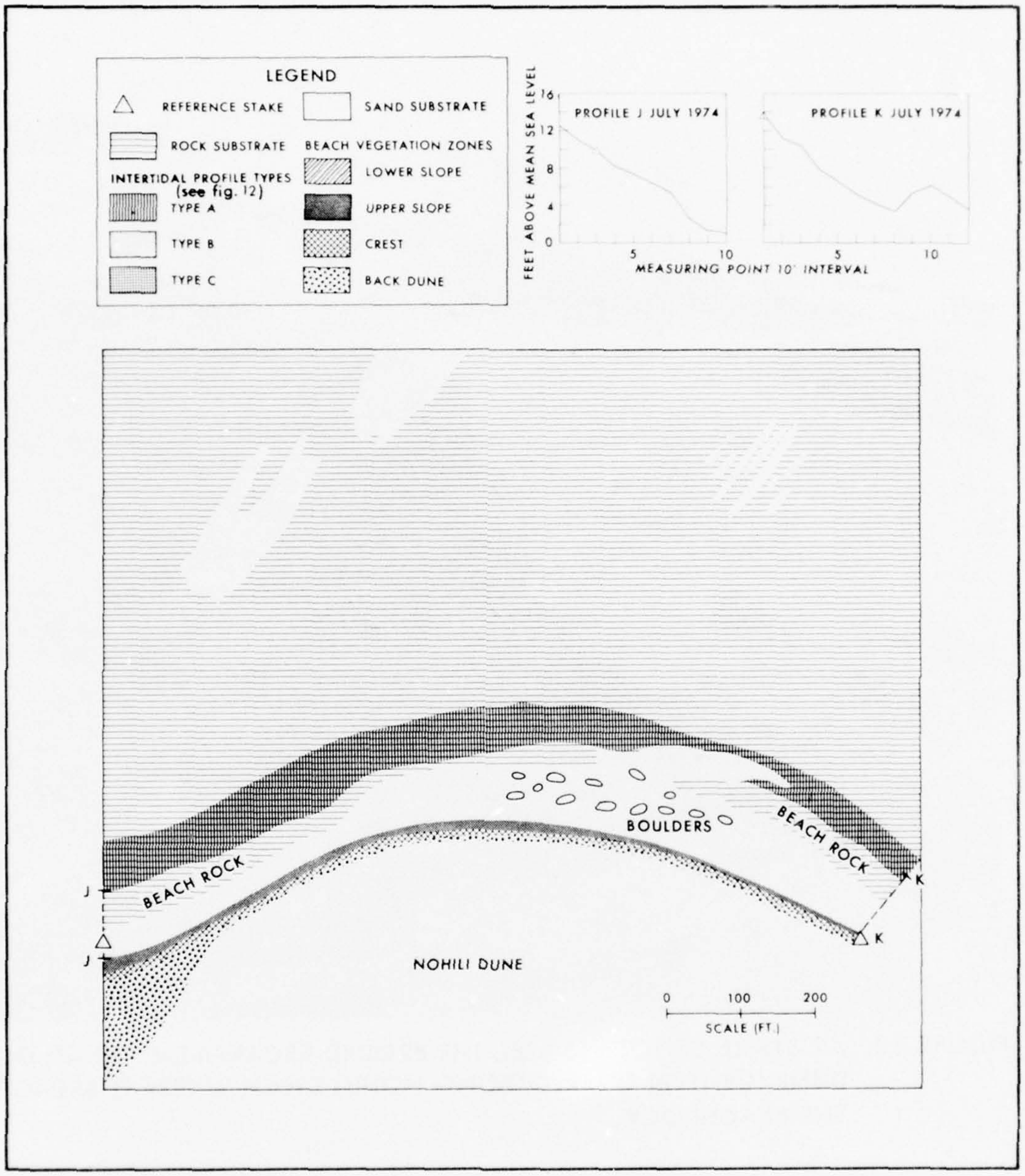


FIGURE 9. BEACH AND SHALLOW ZONE, SECTION J-K (REFER TO FIGURE 1 FOR LOCATION OF SECTION).

FIGURE 10. AT STAKE D (NOT VISIBLE). THE ERODED ESCARPMENT OF AN OLD DUNE (CENTER) OVERLOOKING NOHILI DITCH WHERE IT BREACHES THE BEACHROCK.

Figures 2 through 9 present the beach appearance as observed during the relatively calm summer season. During winter, heavy surf action could be expected to remove large quantities of sand from the beach, deposit it in offshore channels and depressions, and uncover additional beachrock surface.

Four vegetation zones corresponding to physical structures of the beach and forming bands oriented parallel to the waterline were identified. Three of these zones are visible in figure 11. Progressively inshore from the waterline, each of the four zones contained the same species but had more diversity than the preceding zone. Orientation of the zones is shown in figures 2 through 9, and a list of plant species in each zone given in table 1.

1. The lower slope zone.

This zone, nearest the water, lay between 120 and 140 feet (36.6-42.7 m) from the waterline. Located about halfway up the slope to a prominent winter berm crest, this zone has a substrate characterized by loose sand and some isolated beachrock boulders. Ocean water and salt spray reach this zone during storms. The vegetation was sparse, as is to be expected in a salt-spray environment, and consisted of plants that are generally the first to colonize a beach: rushgrass, *Sporobolus virginicus*; beach morning glory, *Ispomoea stolonifera*; and naupaka, *Scaevola taccada*, a semiwoody plant indigenous to Hawaii. This zone was present at reference stakes B, C, G, and H. Eroding areas lacked this zone, especially near reference stakes D, E, F, I, J, and K and areas where beachrock formation did not protect the coastline like that at reference stake A. This zone gradually merges with the upper slope zone.

2. The upper slope zone.

This zone, 10 to 18 feet (3.0-5.5 m) wide, lay about 140 feet (42.7 m) from the waterline and ended 3 or 4 feet (0.9-1.2 m) seaward of the winter berm crest. The substrate was loose sand. Salt spray is probably the most restricting influence to vegetation, as this area is seldom directly subjected to surf. This zone was disturbed by vehicle operations at reference stakes A, B, J, and K. At stations J and K, the zone extended to the base of an escarpment formed by the erosion of Nohili dune. *S. taccada* dominated at reference stakes A and B, and *S. virginicus* dominated at J and K. Near D and E, loose sand was eroding, and *S. virginicus* dominated the sparse vegetation.

The overall vegetation of this zone was spotty, and one or two species dominated large areas. The primary species included those of the lower zone along with beach wire grass, *Dactyloctenium aegyptium*, and the beach vitex, *Vitex ovata*. Of lesser prominence were the morning glory, *Ipomoea pes-caprae* sub-species *brasiliensis*, and the Australian salt bush, *Atriplex semibaccata*.

3. The crest zone

This zone included the last few feet of the slope and the first 8 to 10 feet (2.4-3.0 m) of the top of the winter berm. Near reference stakes J and K, the zone began at the bottom of the escarpment. Fifteen species were observed in this zone. The dominant species were sandbur, *Cenchrus echinatus*; Bermuda grass, *Cynodon dactylon*; beach wire grass, *Dactyloctenium aegyptium*; naupaka, *Scaevola taccada*; rushgrass, *Sporobolus virginicus*; and beach vitex, *Vitex ovata*. Other species present included wild tamarind, *Leucaena latisifua*; the golden-crown-beard, *Verbesina encelioides*; and *Boerhavia diffusa*.

FIGURE 11. AT STAKE J (CENTER) LOOKING EAST. THREE VEGETATION ZONES ARE VISIBLE: UPPER SLOPE, CREST, AND BACK DUNE.

Table 1. Beach plant species and zonation

		Lower Slope Zone	Upper Slope Zone	Crest Zone	Back Dune Zone
Acacia farnesiana	Acacia			+	*
Atriplex semibaccata	Australian salt bush		+	+	+
Boerhavia diffusa				+	+
Cenchrus echinatus	Sandbur			*	*
Chenopodium sp.	Mexican tea				+
Chenopodium ambrosioides	Mexican tea				+
Chloris virgata	Feather fingergrass				+
Cynodon dactylon	Bermuda grass			*	*
Dactyloctenium aegyptium	Beach wire grass		*	*	*
Euphorbia hirta					+
Ipomoea pes-caprae Subsp. *brasiliensis*	Purple flowered beach morning glory		+	+	+
Ipomoea stolonifera	White flowered beach morning glory	+	+	+	+
Leucaena latisifua	Wild tamarind			+	*
Panicum maximum				+	+
Pluchea indica	Indian pluchea				+
Pluchea x. fosbergii	Indian pluchea				+
Portulaca cyanosperma	Blue-seeded portulaca				+
Portulaca oleracea	Common purslane			+	+
Scaevola taccada	Naupaka	+	*	+	+
Sida cordifolia	Panatropic sida				+
Sporobolus virginicus	Seashore rushgrass	*	*	*	*
Verbesina encelioides	Golden-crown-beard			+	+
Vitex ovata	Beach vitex		*	*	*
Waltheria americana	Hi'aloa			+	+

* Indicates dominant species of that zone
\+ Indicates non-dominant species of that zone

Bermuda grass, Cynodon dactylon, dominated areas that appeared to have been cleared of vegetation and were heavily trafficked.

4. The back dune zone

This zone lay between the crest zone and the brush line and varied in width from 10 feet (3 m) at reference stake K to 200 feet (61 m) at stake I.

Partly protected from salt spray by the winter berm crest, this zone contained a diverse plant community which included all of the 24 plant species collected in the study area. Part of the zone had been cleared and was regularly disturbed by vehicle traffic. The zone at A and B was dominated by S. virginicus, Acacia farnesiana, and L. latisifua. A large, cleared antenna site between stakes C and D was dominated by the sandbur, Cenchrus echinatus; beach wire grass, D. aegyptium; and Bermuda grass, C. dactylon.

Near reference stakes E, F, and G, where the brushy A. farnesiana and L. latisifua had been cleared, C. dactylon was dominant. The large area between stakes H and I was dominated by C. dactylon and by the sprawling brush plants Pluchea indica and P. x. fosbergii, which formed thickets several hundred feet square. At stake J the zone was about 140 feet (42.7 m) wide and was dominated by beach vitex, V. ovata, which covered about 90 percent of the zone. The narrow back dune zone between J and K was dominated by S. virginicus and A. farnesiana. The onshore boundary of the back dune zone was marked by a narrow band of the grass, Panicum maximum, and the golden-crown-beard, V. encelioides.

B. Intertidal Zone

The intertidal zone extends from mean low water to the onshore limit of sand or beachrock that is normally influenced by wave action. Within this zone there were three types of shore formations, each characterized by a distinct profile. Figures 2 through 9 present plan views of the intertidal zone showing the sites where the three profile types were represented. The distinguishing topographic features which characterized the three profile types are shown in figure 12.

The intertidal zone community contained some of the highest concentrations of plant and animal material (biomass) in the Barking Sands nearshore marine environment. An extensive rock substrate, the constant wash of surf, and the intense sunlight produce an ideal environment for numerous attached algae and the animals which graze on them. This zone provides a source of plant material for the entire marine community.

The intertidal zone is harvested by the human population. Enteromorpha (limu eleele) and Ulva (limu pahapaha) are two of several algae utilized in the human diet, as are the echinoderm (sea urchin), Colobocentrotus (Podaphora) atrata, and the limpet, Cellana exarata.

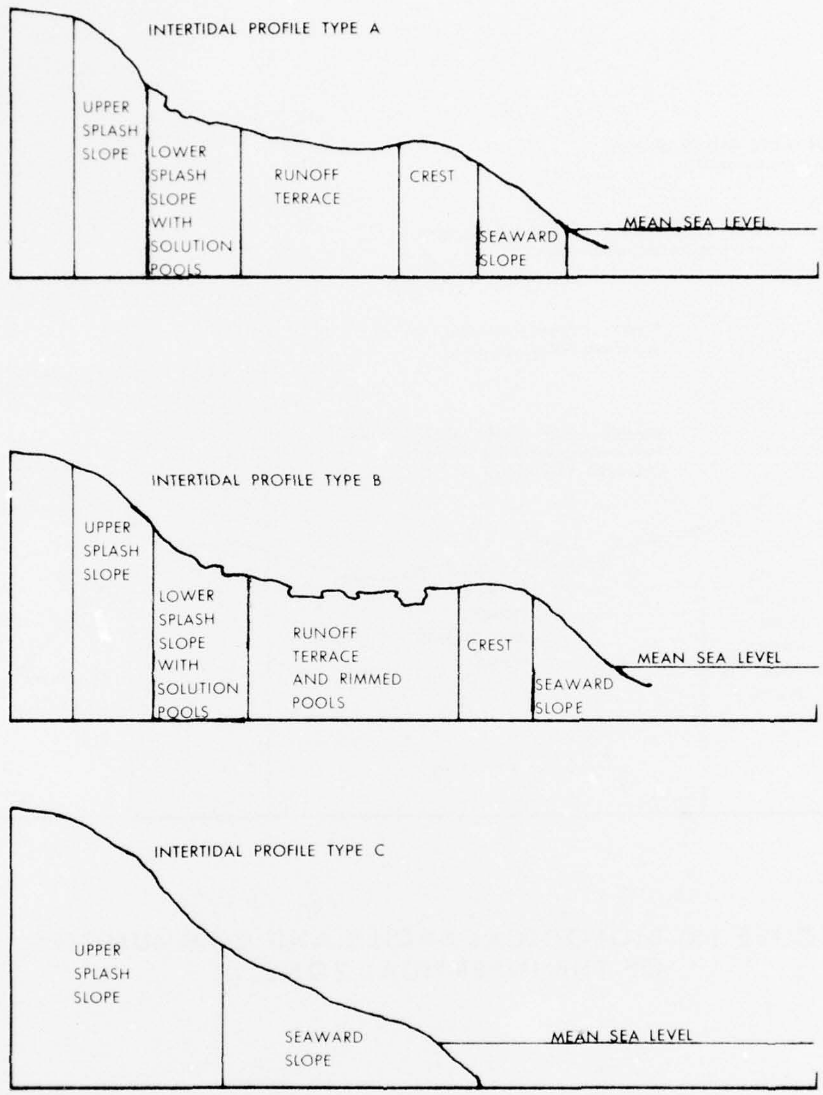


FIGURE 12. INTERTIDAL PROFILE TYPES

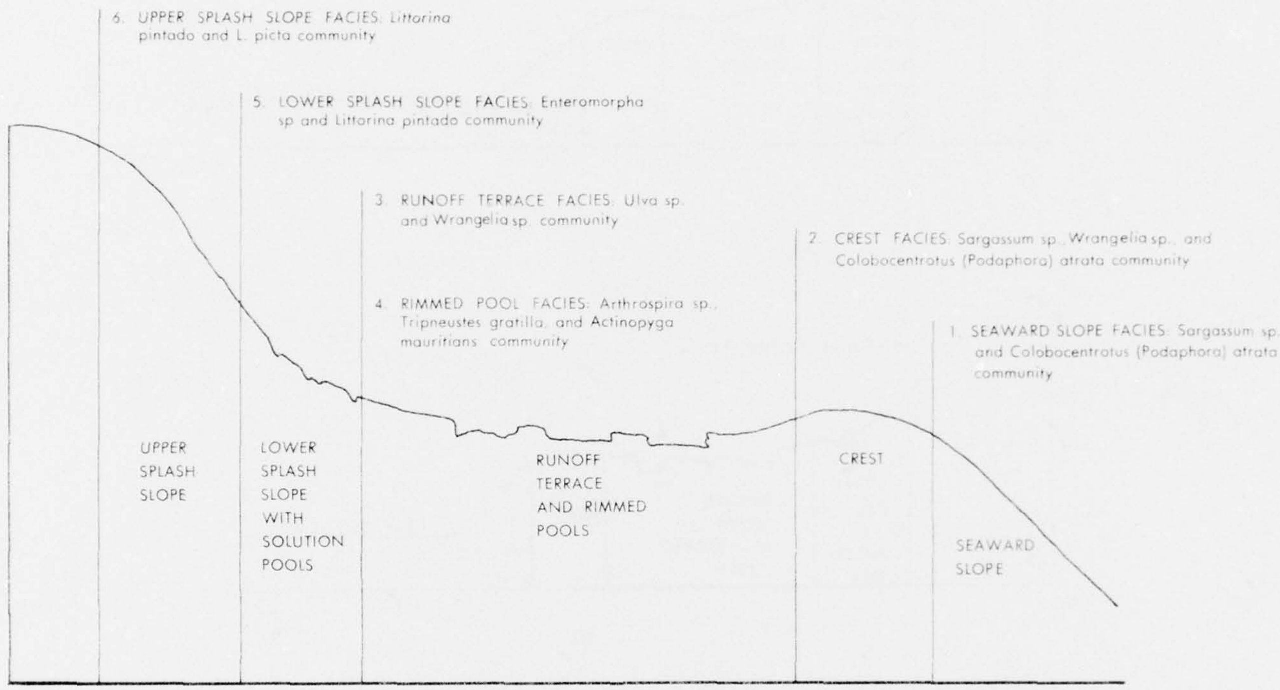


FIGURE 13. BIOLOGICAL FACIES AND COMMUNITIES OF THE INTERTIDAL ZONE.

Six distinct environmental facies were identified, each containing a characteristic biological community. These are shown diagramatically in figure 13.

The high energy seaward slope and crest facies are subject to the full force of waves. The slope facies community was dominated by the alga, Sargassum. There were sparse occurrences of the alga, Wrangelia, and the echinoderm, C. atrata. The crest facies community was dominated by Sargassum, Wrangelia, and C. atrata. There were frequent occurrences of the algae Ulva, Hydrocoleus, and Padina and of the echinoderms, Echinometra oblonga and E. mathaei. Occurring in lesser quantities were the algae Colpomenia, Arthrospira, and Jania. E. oblonga and E. mathaei occurred on the top of the crest in depressions formed by the animals. A fish, Bathygobius, was common between the seaward slope facies and the rimmed pool facies, migrating from facies to facies with the tide.

The runoff facies, protected from the full force of the waves by the crest, was continually submerged and strongly washed. The community of the runoff facies was dominated by the algae, Ulva and Wrangelia. From Nohili Ditch to about 800 feet (244 m) south, this facies was dominated by a dense Ulva community, probably influenced by fresh water from Nohili Ditch. Also present in the runoff facies community were the algae, Turbinaria, Dictyosphaeria, Jania, and Spyridia; the echinoderms, C. atrata, E. oblonga, and E. mathaei, were scarce.

The rimmed pool facies, located within the confines of the runoff terrace, was a more sheltered environment than the runoff facies and supported a community of more delicate organisms. The dominant organism was Arthrospira; frequently occurring were the algae, Ulva, Padina, Cladophora, Valonia, Zonaria, and Galaxaura, an echinoderm, Tripneustes gratilla, and a holothurian, Actinopyga mauritians. Both T. gratilla and A. mauritians were more common north of Nohili Ditch, where the rimmed pools were better protected by a higher crest.

The lower splash slope facies, containing solution pools, is frequently reached by the surf. Dominant within the pools were the filamentous alga, Enteromorpha, and the gastropod, Littorina pintado. There were traces of the algae, Arthrospira and Lyngbya, and a few of the gastropods, Nerita picea and Cellana exarata, under rocks and in crevices.

The upper splash slope facies, only occasionally wetted by higher tides and surf, contained a community represented by few algae and two gastropods, L. pintado and L. picta. Both gastropods were clustered in shaded crevices and under rocks.

C. Shallow Zone

1. Environment and topography

A sparsely populated coral reef is present on the western coast of Kauai at Nohili Point. Physical development of the reef is characteristic

of many Hawaiian reefs (Gosline and Brock, 1960). Water clarity, bottom composition, and surge intensity influence the benthic populations.

The shallow zone extends from the intertidal zone to the 20-foot (6.1 m) depth, an area 700 to 1,300 feet (213-396 m) wide. A turbid, high energy surge zone characterized the study area to about the 40-foot (12 m) depth. Much of the turbidity, originating as silt flowing from Nohili Ditch, was concentrated in an area about 1,000 feet (305 m) to the north and south of the ditch. Beyond the 40-foot (12.2 m) depth was a moderate to low energy environment of moderate to slight turbidity.

The area from the intertidal zone to about 100 feet (30.5 m) offshore was a high energy surf zone. Between stakes A and E, the bottom, consisting of sand and rock, gradually sloped to a depth of about 3 feet (1 m). Between stakes F and K, where the beachrock had collapsed, a 2- to 4-foot (0.6-1.2 m) escarpment occurred at the waterline. At stakes F, I, and J, the collapsed beachrock extended 50 to 80 feet (15-24 m) offshore and formed a boulder zone with 2- to 4-foot relief in 6 to 10 feet (2-3 m) of water. Between stakes G and H and off stake K, an algae-covered terrace 50 to 100 feet (15.2-30.5 m) wide lay in 1 to 2 feet (0.3-0.6 m) of water directly off the beach.

Seaward of the surf zone a shallow trough 100 to 300 feet (30.5-91.4 m) wide lay between the submerged beachrock and a rocky shoal that rose in places to within 1 foot of the surface. Sand pockets and rubble were present in the trough, but most of the bottom was consolidated rock. A thin veneer of sand was present in the trough near stakes I and J.

The shoal, lying lengthwise to the coast from 100 to 400 feet (30.5-121.9 m) offshore, was narrow and discontinuous. The shoal was 2 to 3 feet (0.3-0.9 m) deep off stakes A, B, C, D, F, and G and about 1 foot deep off stake E. Seaward of the shoal, about 400 feet (121.9 m) offshore, the water was 10 to 12 feet (3.0-3.7 m) deep and the bottom formed low rocky spurs, plateaus, and narrow channels with some sand. At 500 feet (152.4 m) offshore the depth increased to 12 to 15 feet (3.0-4.6 m), and the spurs and plateaus became distinctly separated by sand channels and flats, which extended beyond the 20-foot (6 m) depth and into the deep zone. Major sand flats were present off stakes A, B, F, I, and J.

2. Biological communities

Results of the shallow zone line transects and meter-square counts are presented in tables 2 and 3.

Algae dominated the shallow zone and covered about 50 percent of the bottom. Of the 23 genera of algae recorded from the shallow zone, four were common: (1) Lyngbya, occurring in 50 percent of the meter-square counts, covered 22 percent of the bottom; (2) Wrangelia, occurring in 32 percent of the counts, covered about 12 percent of the bottom; (3) Arthrospira, occurring in 20 percent of the counts, covered 5 percent of the bottom; and (4) Sargassum, occurring in 17 percent of the counts,

Table 2. Shallow zone transects coral tabulations
(numbers of individuals)

SHALLOW TRANSECT LINE	DISTANCE FROM WATERLINE (FEET)	DEPTH RANGE (FEET)	*Porites lobata*	*Porites compressa*	*Pocillopora meandrina*	*Montipora verrucosa*	*Pavona sp.*
A	85-185	4- 5					
	185-285	5- 6	4				
	285-385	6-10	4		2		
	385-485	10-12	3	1	1		
B	80-100	4- 9	9		4		
	180-280	9-10	8	2	2	1	
	280-380	10-15	16		6	1	
	380-480	13-15	17	2	3	1	2
E	100-200	2- 4		13			
	200-300	4- 5		10	1		
	300-400	5- 6	1	5	5		
	400-500	6-10		6	6	1	1
F	20-120	2- 7		3	1		
	120-220	7- 9		10	1		
	220-320	9- 9		11			
	320-420	9-12	1	2	6		
G	50-150	2- 7	3	4	2		
	150-250	7- 9	2	2	5		
	250-350	9-10	1	1	7		
	350-450	10-13	6	2	2		
	450-550	13-16	4	3	1	3	
H	20- 50	2- 2	4	2	3		
	50-150	2- 4		12	1		2
	150-250	4- 5		8	5	1	
	250-350	5- 6	3	7	9	1	1
	350-450	6-10		13	3	2	
I	20-100	4- 8			5		
	100-200	8-11	5	6	2	2	
	200-300	11-11	4	5			
	300-400	11-12	4	1	3		2
	400-500	8-12	6		6	1	
K	100-180	3- 6	1		4		
	180-280	6- 7	8				
	280-380	7- 9	8		1	3	
	380-480	9-11	3			3	

Table 3. Shallow zone meter-square tabulations and fish counts

SHALLOW TRANSECT LINE	DISTANCE FROM WATERLINE (ft)	DEPTH (ft)	ALGAE - PERCENT COVERAGE + = less than 1%																								
			Acanthophora sp.	Arthrospira sp.	Caulerpa sp.	Colpomenia sp.	Dasya sp.	Dictyota sp.	Ectocarpus sp.	Enteromorpha sp.	Halimeda sp.	Hydrocoleus sp.	Jania sp.	Lyngbya sp.	Neomeris sp.	Corallinaceae (crustose)	Padina sp.	Rivularia sp.	Sargassum sp.	Sphacelaria sp.	Spyridia sp.	Turbinaria sp.	Ulva sp.	Valonia sp.	Wrangelia sp.	Acanthuridae Surgeonfish	Apogonidae
A	85	4		30											+												
	185	5		30														+									
	285	6		10							+			70													
	385	10		10					+					40						+							
	485	12					+													20					70		
B	80	4				+								80											+		
	180	9												+											40		1
	280	10												+					+						40		
	380	15												30											40	4	
	480	13												20											20		
E	100	2																	100								
	200	4						+						80			+					+					
	300	5												70			+					+					
	400	6											+	60			+		+								
	500	10											+	30	+	+											
F	20	2							50														+		40		
	120	7																					10		70		
	220	9														+	10						10		10		
	320	9														+	40								40		
	420	12						+								+	10										
G	50	2		10									+									10	+				
	150	7	30								+											+	+				
	250	9		70																							
	350	10	40	20																							
	450	13		30					+		+		+		+	+									30		4
	550	16													+		20				+					15	
H	50	2											40												40		
	150	4					+				+								80								
	250	5			+									70		20	+										
	350	6											+														
	450	10						+							+	+			80								
I	100	8								+	+			70													
	200	11												40													
	300	11												50			+	+									
	400	12												20										+			
	500	8			30							10		20										+			
K	100	3				+					+		+	20					+								
	180	6									+		+	40	+												
	280	7									10		+	20											30		
	380	9						+			+			40													
	480	11			+						+		10	30													

					FISH - NUMBER COUNTED																							CORAL - % COVER + = less than 1%					
Spyridia sp.	Turbinaria sp.	Ulva sp.	Valonia sp.	Wrangelia sp.	Acanthuridae Surgeonfish	Apogonidae Cardinal Fish	Balistidae Triggerfish	Belonidae Needlefish	Chaetodontidae Butterfly Fish	Dussumieriidae Typical Herring	Elopidae Ladyfish	Engraulidae Herring	Eleotridae, Gobiidae Kraemeriidae-Gobies	Holocentridae Squirrelfish	Kyphosidae Rudder Fish	Labridae Wrasses	Mugilidae Mullet	Muraenidae Moray Eel	Ostraciontidae Cowfish	Polynemidae Threadfin	Pomacentridae Damselfish	Scaridae Parrot Fish	Scorpididae Convict	Squalidae Dogfish	Carangidae Jack	Tetraodontidae Puffer	Zanclidae Idol	Porites lobata	Porites compressa	Pocillopora sp.	Montipora sp.	Pavona sp.	Cyphastrea sp.
				70			4		2 2				2 1								1							2 15	2				
				+ 40 40 40 20	4	1	2 2		3 2	7	2 1	4 4	5 4 1 2						1		5				10		2	5 7 23 5		1			2
	+ +						1		1		1	2 2	1 1 1 2	1								1 2						2 5	+				
		+ 10 10		40 70 10 40				+			10 10		4 10 20											1					+ 10 +				
+	10 +	+ +		30	15	4	2		5	2 2	1 2 7	2 1	4 4	4 2 1 1	2	3	10				4	4 5							+ +	4 8	+ +		
				40					1	4			1 1		2				2		1 1	2						2 2	10	5 3 2 4		2	
			+ +				2 14	28	2 2 4 2	5 1 2	4		3 4 4	4	4		4 2	1		6	2 14 2					1		2 + 4	6				
				30			3		100 25 20 20	3			4 2 10 20 10								5 2		1				2 2	+ 2 +	+ +	+ +			

2

covered 5 percent of the bottom. Crustose Corallinaceae, the articulated coralline, Jania, and the green calcareous alga, Halimeda, occurred in about 20 percent of the counts, each covering less than 2 percent of the bottom. The most common alga, Lyngbya, decreased in prominence near sand basins; along transect lines F, G, and H; at the nearshore area of transect line A; and at the 10-foot (3 m) depth 200 to 300 feet (61.0-91.4 m) offshore on transect line B. Seasonal offshore movement of sand probably inhibits the growth of this filamentous alga by burying, scouring, and by reducing water clarity. The areas lacking Lyngbya were populated by either Wrangelia or Arthrospira and one or more of the algae, Sargassum, Turbinaria, Padina, and Jania, which are larger, sturdier plants.

The sparse coral population was dominated by the genus Porites. The paucity of corals was probably caused by the silty environment. Edmondson (1928) described a similar effect of a silty environment for a section of the Waikiki reef. The genera Pocillopora, Montipora, Favia, Pavona, and Cyphastrea were present. The composition of the sparse coral population was homogeneous throughout the shallow zone. In the surf zone, the first 100 feet (30.5 m) from shore, corals covered less than 1 percent of the bottom. From the surf zone to the 20-foot (6 m) depth, coral covered about 3 percent of the bottom. Porites, covering about 2.5 percent of the bottom, occurred in 60 percent of the meter-square counts and accounted for 67 percent of coral occurrences on transect lines. Pocillopora, covering about 0.7 percent of the bottom, occurred in 22 percent of the counts and accounted for 25 percent of the coral occurrences on the transect lines. The other genera, covering less than 0.1 percent of the bottom, occurred in about 14 percent of the counts and accounted for about 8 percent of the coral occurrences on transect lines.

The relatively small fish population of the shallow zone was composed of characteristic reef fish (Gosline and Brock, 1960). Twenty-five families of fishes were recorded. The four most common families were Chaetodontidae (butterfly fish) and the three families of gobies: Kraemeriidae, Eleotridae, and Gobiidae. Butterfly fish occurred at 39 percent of the counting stations and accounted for 32 percent of the fish population. Gobies occurred at 66 percent of the counting stations and accounted for 21 percent of the fish population. Most of the fish occurred in water depths of 6 or more feet (1.8 m) and congregated around ledges, boulders, and rocky heads. The areas off stakes I and K were more abundantly populated than areas off stakes A, E, and H.

Approximately 10 large sea turtles were observed in the shallow zone during the investigations; however, they do not appear in the population counts. Numerous spiny lobsters (Panulirus sp.) were also observed, particularly off reference stake I.

The Barking Sands area was moderately used by local spearfishermen and throw-net fishermen, particularly during weekends. The greatest activity was near reference stakes H, I, and J. Surgeonfish (Acanthuridae), damselfish (Pomacentridae), and butterfly fish (Chaetodontidae) were observed among the catches.

D. Deep Zone

1. *Environment and topography*

The deep zone includes the section of reef between the 20- and 80-foot (6.1-24.4 m) depths, an area varying in width from 4,000 feet (1,219 m) off Nohili Point to 4,500 feet (1,372 m) off reference stake A. Results of the bathymetric survey are shown in figure 1. Figure 15 shows the general biological zonation and the distribution of rock and sand substrate.

Between the 20- and 50-foot (6.1-15.2 m) depths, an area 1,700 to 2,300 feet (518-701 m) wide, the bottom consisted of a series of connecting rocky spurs and plateaus with 5- to 10-foot (1.5-3.0 m) relief and a scattering of discontinuous sand flats and channels lying normal to the coast. The sand expanses, 400 to 600 feet (121.9-182.9 m) long and as wide as 60 feet (18.3 m), comprised 30 to 60 percent of the bottom. The sand expanses were most common in the areas between stakes B and H. Three sand flats off stakes B, F, and K extended shoreward to the 10-foot depth.

Between the 50- and 65-foot (15.2-19.8 m) depths, an area 700 to 1,200 feet (213.4-366.0 m) wide, the bottom was irregular, with numerous holes and channels creating a relief of 3 to 4 feet (0.9-1.2 m). Sand, comprising 5 to 20 percent of the bottom, had collected in the holes and channels.

Between the 65- and 70-foot (19.8-21.3 m) depths, an area 400 to 500 feet (121.9-152.4 m) wide, was a uniform rock bottom with 2- to 3-foot (0.6-0.9 m) relief. Sand, covering less than 5 percent of the bottom, formed a thin veneer in depressions.

2. Biological communities

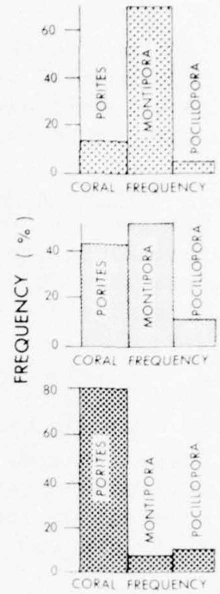
A stratified population, dominated by three genera and five species, characterized the deep zone. The coral species were Montipora verrucosa, Montipora sp., Porites lobata, Porites compressa, and Pocillopora meandrina. The coral genera Porites (Synaraea), Cyphastrea, Favia, and Pavona were also present. The density of coral (percentage of bottom covered by coral) increased from 5 to 15 percent at the 20-foot (6.1 m) depth to about 30 percent at the 70-foot (21.3 m) depth. The numbers of coral colonies also increased with depth. Relative frequencies of occurrence of the three common genera (table 4) show coral species dominance and depth range.

Porites, a silt tolerant genus often characteristic of high energy environments, was the dominant coral between the 20- and 30-foot (6.1-9.1 m) depths. Porites compressa was concentrated on rocky spurs and plateaus as fingerlike projections, with much of the basal portion covered by rubble and overgrown by algae (see figs. 15 and 16). In the 20- to

DEPTH—50 TO 70 FEET (15.2-21.3 M); SAND CHANNELS NARROW AND INFREQUENT; CORAL COVERS 25% TO 30% OF BOTTOM; CORAL COMMUNITY DOMINATED BY MONTIPORA; ALGAL POPULATION DIVERSE, WITH WRANGELIA AND JANIA COMMON.

DEPTH—30 TO 50 FEET (9.1-15.2 M); SAND CHANNELS NUMEROUS; CORAL COVERS 15% TO 25% OF BOTTOM; TRANSITION ZONE BETWEEN SHALLOW PORITES ENVIRONMENT AND DEEPER MONTIPORA ENVIRONMENT; COMMON ALGAE ARE WRANGELIA AND JANIA.

DEPTH—20 TO 30 FEET (6.1-9.1 M); TURBID HIGH ENERGY ENVIRONMENT; WIDE SAND CHANNELS; CORAL 5% TO 15% OF BOTTOM; CORAL COMMUNITY DOMINATED BY PORITES; ALGAL COMMUNITY DOMINATED BY ENCRUSTING CORALLINACEAE.



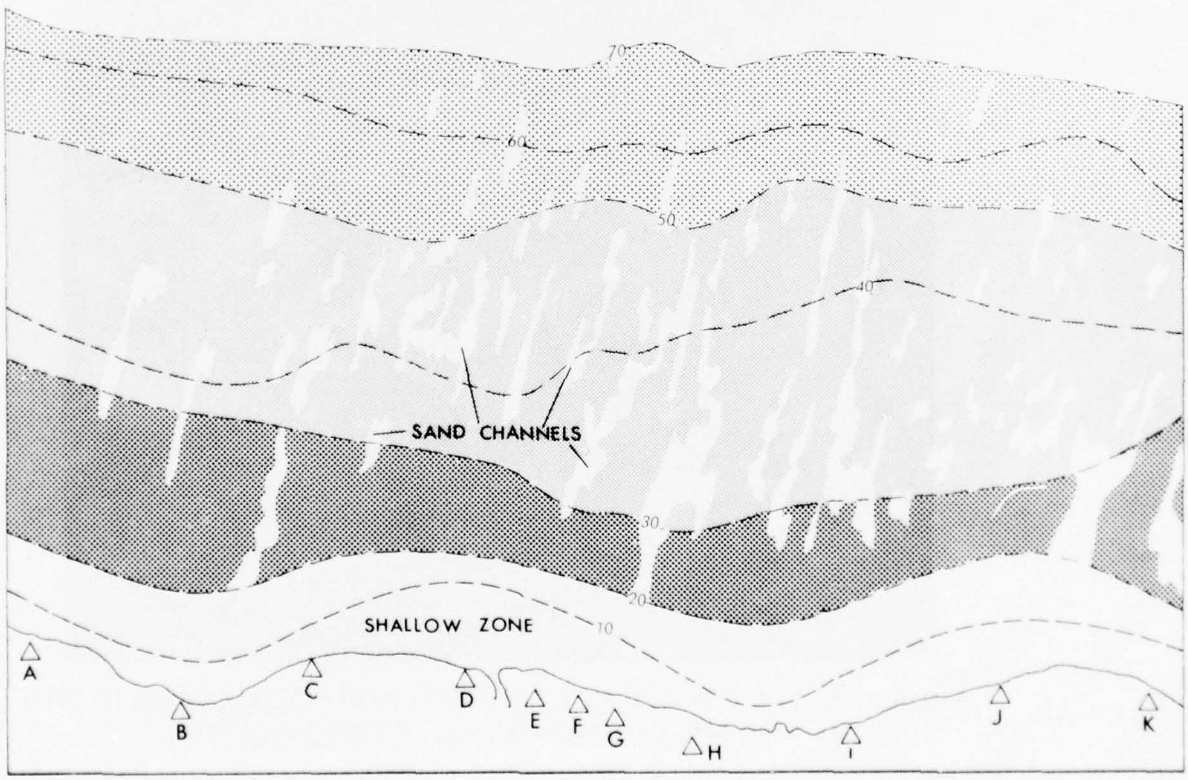


FIGURE 14. DEEP ZONE BIOLOGICAL ZONATION AND DISTRIBUTION OF SAND CHANNELS.

30-foot depths, coral density was greatest at transect lines I, J, and K. The general paucity of coral at this depth indicates that the sand bottom and turbid water are poor conditions for coral growth. Porites occurred throughout the deep zone, but few grew deeper than 65 feet (19.8 m).

Montipora was dominant at 50- to 70-foot (15.2-21.3 m) depths. Between the 30- and 50-foot (9.1-15.2 m) depths Porites and Montipora were about equal in frequencies of occurrence (see fig. 16). In depths less than 25 feet (7.6 m), Montipora, restricted by the turbid water, accounted for less than 10 percent of the coral.

Pocillopora was sparse throughout the area in depths less than 70 feet (21.3 m). The small amount of data taken from 70- to 80-foot (21.3-24.4 m) depths indicates that Pocillopora may be absent or rare in these deeper waters. This coral probably requires the moderate to high energy environment found in depths less than 50 feet (15.2 m), but it is not tolerant of more turbid environments. An example of Pocillopora is shown in figure 15.

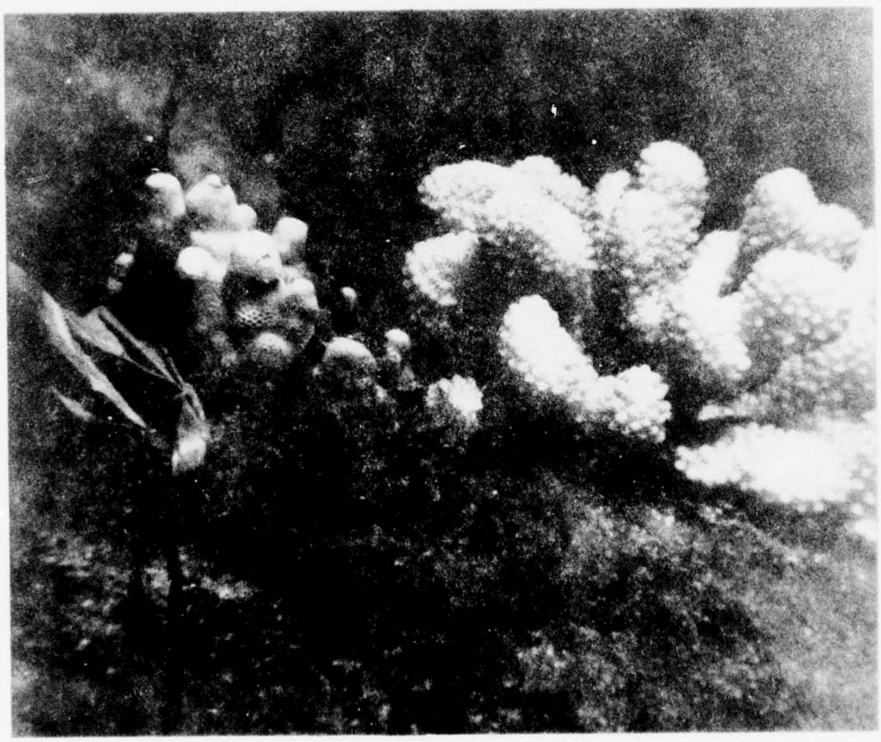


FIGURE 15. THE CORALS, PORITES (LEFT) AND POCILLOPORA (RIGHT), AND THE COMMON ALGA, ENTEROMORPHA.

Table 4. Deep zone transects coral tabulations (numbers of individuals)

DEEP TRANSECT	DEPTH RANGE (ft)	*Porites* sp.	*Montipora* sp.	*Pocillopora* sp.
B	70-60	17	70	7
	60-50	15	36	5
	50-40	29	24	9
C	50-40	26	29	12
	40-30	12	18	0
	30-20	55	6	5
D	70-60	19	57	6
	60-50	24	38	3
	50-40	40	41	2
	40-30	13	12	9
E	70-60	12	50	0
	60-50	14	66	5
	50-40	13	44	10
	40-30	64	68	13
	30-20	36	4	3
H	70-60	19	31	0
	60-50	30	77	8
	50-40	10	16	7
	40-30	16	21	9
I	50-40	45	38	5
	40-30	69	35	13
K	50-40	21	31	4
	40-30	23	28	18
	30-20	60	10	19

A diverse algal population dominated the deep zone. Jania, Ectocarpus, Turbinaria, Wrangelia, and the crustose Corallinaceae were common.

Crustose Corallinaceae were the most common algae at the 20- to 35-foot (6.1-10.7 m) depths and were encrusted on dead coral skeletons, mainly Pocillopora. Jania was prominent off stakes C, F, I, and K at the 30-foot (9.1 m) depth, covering up to 100 square feet (9.3 sq m), with concentrations of 3 to 4 plants per square foot. Between the 35- and 80-foot (10.7-24.4 m) depths the most common genera were Jania, Ectocarpus, Turbinaria, and Wrangelia. A green filamentous alga, possibly Enteromorpha, grew at the 50-foot (15.2 m) depth off stake C and carpeted large sections of the rock bottom. Along transect H at the 70-foot (21.3 m) depth Ulva formed a green cover over the rock, a unique occurrence. The coral population of this area was also unique in being dominated by Porites, rather than Montipora as was characteristic of other areas at this depth. Both Ulva and Porites are characteristic of a high-energy environment.

Sponges in the deep zone were small and generally incrusted on and under rocks and ledges. Time was insufficient to search for the sponges while observers swam the transect lines; recorded sponges were types that grew in the open. The most frequently observed sponge was a small, green and black specimen, possibly Spirastrella vagabunda, that grew under a thin layer of sand with only the oscules protruding.

Over 1,700 fish representing 25 families were recorded in the deep zone. All of the families are common to the coral reefs of the Hawaiian Islands (Gosline and Brock, 1960). A tabulation of occurrences by family is presented in table 5. Eighteen of these families were also recorded in the shallow zone. Most of the fish were congregated around rocky heads and near ledges. As depth increased in the deep zone and as the heads and ledges became fewer, the fish population became less diverse and smaller. The relationship of fish to characteristic habitats is discussed by Brock (1954) and Gosline and Brock (1960). About 90 percent of the fish counted belong to 10 families: Gobiidae (gobies), Kraemeriidae (gobies), Eleotridae (gobies), Chaetodontidae (butterfly fish), Labridae (Wrasses), Balistidae (triggerfish), Dussumieriidae (typical herring), Pomacentridae (damselfish), Holocentridae (squirrel-fish), and Ostraciontidae (cowfish). The gobies accounted for 44 percent, the butterfly fish, for 11 percent, and the other six families, for 35 percent of the total fish count.

E. Quadrats

Quadrat 1 (figure 18) is located at a depth of about 45 feet (13.7 m) on line transect G on the top of a rocky plateau. The water was clear when the quadrat was surveyed, but there was some fine sediment on the algae and corals. The quadrat probably lay on the edge of the area influenced by sediment from the Nohili Ditch. Algae accounted for 75 percent of the bottom coverage; corals, 23 percent. The alga Spyridia was dominant with 70-percent bottom coverage. Crustose coralline algae

Table 5. Deep zone transects fish counts (numbers of individuals)

	OCCURRENCES											
	TRANSECT LINE B				TRANSECT LINE D					TRANSECT LINE K		
	DEPTH RANGE (ft)				DEPTH RANGE (ft)					DEPTH RANGE (ft)		
	40-50	50-60	60-70	70-80	30-40	40-50	50-60	60-70	70-75	20-30	30-40	40-50
Gobies:Gobiidae, Kraemeriidae, Eleotridae	100	100	50	60	110	50	20	-	35	110	80	32
Butterfly Fish:Chaetodontidae	20	60	26	5	10	2	10	10	-	10	6	22
Wrasses:Labridae	25	2	2	11	24	-	10	22	30	10	2	2
Triggerfish:Balistidae	60	-	4	-	8	11	20	8	4	4	5	4
Typical Herring:Dussumieriidae	-	-	-	-	-	-	-	100	-	-	-	-
Squirrelfish:Holocentridae	2	20	-	10	10	-	-	5	2	10	15	12
Cowfish:Ostraciontidae	4	4	6	5	10	10	-	-	6	16	2	3
Damselfish:Pomacentridae	25	-	-	-	15	4	14	4	-	4	-	-
Jacks, Pompano:Carangidae	5	-	-	-	-	2	-	-	-	50	-	-
Surgeonfish:Acanthuridae	-	2	6	-	10	6	4	-	6	10	-	-
Silversides:Atherinidae	4	-	-	-	-	-	4	6	-	-	-	5
Idol:Zanclidae	2	-	5	-	-	-	2	-	-	3	2	2
Needlefish:Belonidae	-	9	-	-	-	-	-	-	-	7	-	-
Dolphin:Coryphaenidae	-	-	-	-	-	-	14	-	-	-	-	-
Herring:Chanidae	-	-	2	-	10	-	-	-	-	-	-	-
Pipefish:Syngnathidae	-	5	-	-	-	-	-	-	-	-	-	-
Conger Eel:Congridae	1	1	-	-	-	-	-	-	-	-	-	-
Threadfin:Polynemidae	4	-	-	-	-	-	-	-	-	-	-	-
Puffer:Tetraodontidae	-	-	-	-	2	-	-	-	2	-	-	-
Cornet Fish:Fistulariidae	-	-	-	-	2	-	2	-	-	-	-	-
Hawkfish:Cirrhitidae	-	-	-	-	-	-	2	-	-	-	-	1
Moray Eel:Muraenidae	-	1	-	-	1	-	-	-	-	-	-	-
Convict:Scorpididae	-	-	-	-	1	-	-	-	-	-	-	-

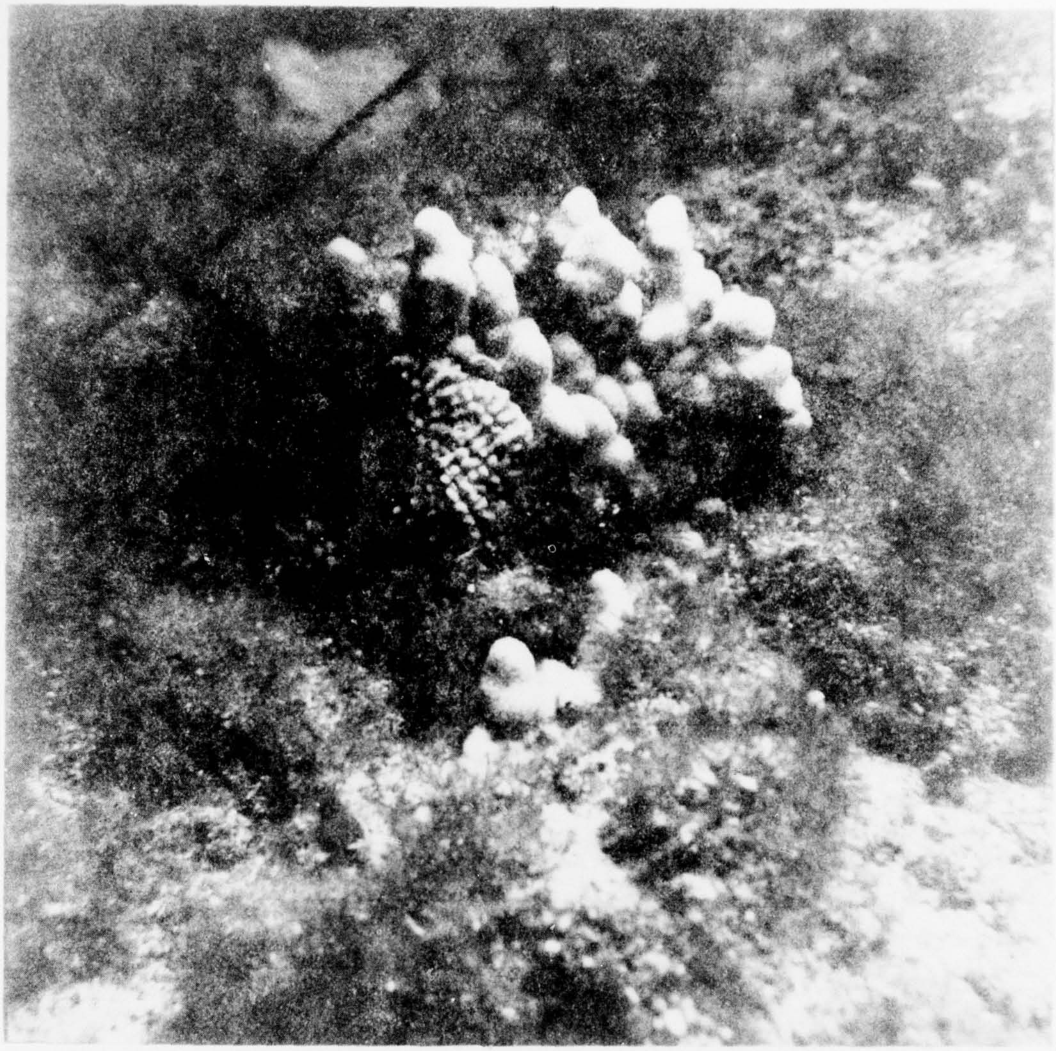
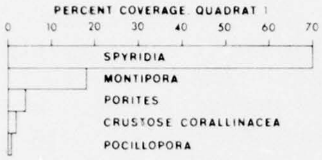


FIGURE 16. THE CORALS MONTIPORA (LEFT) AND PORITES (RIGHT) SURROUNDED BY THE ALGA ENTEROMORPHA.

accounted for 2-percent coverage. Jania, Halimeda, Padina, Neomeris, Wrangelia, and Sphacelaria accounted for 3-percent coverage. The dominant coral was Montipora, with 18-percent coverage. Porites and Pocillopora comprised 4-percent and 1-percent coverage, respectively. Pavona and Porites (Synaraea) were also represented.

Quadrat 2 (figure 19) at the 30-foot (9.1 m) depth was located on the top of a rocky spur on transect line I. The water was slightly turbid, and a thin layer of silt was present on the rock. Algae comprised less than 10 percent of the quadrat area; corals, 37 percent. The dominant alga was Cladophora, with 4-percent coverage. Other common algae were Caulerpa, with 1-percent coverage, Hydrocoleus, Valonia, Jania, Halimeda, Padina, Neomeris, and Spyridia, each with less than 1-percent coverage. The dominant coral was Porites, with 33-percent coverage. Montipora accounted for 2-percent coverage and Pavona and Pocillopora each about 1-percent coverage.

FIGURE 17. OCEANOGRAPHER/DIVER DOCUMENTING QUADRAT 2.



KEY TO QUADRAT SKETCHES

2B. P. meandrina Dana
2C. P. damicornis (Linnaeus)
4A. P. lobata Dana
4B. P. compressa Dana
4F. P. (Synaraea) sp. Verrill
9. Montipora sp. de Blainville
9A. M. verrucosa (Lamarck)
16. Pavona sp. Lamarck
X. Unidentified Sponge
Z. Anemone
NU. Crustose Corallinaceae

AREA SHOWN IS 5M X 5M

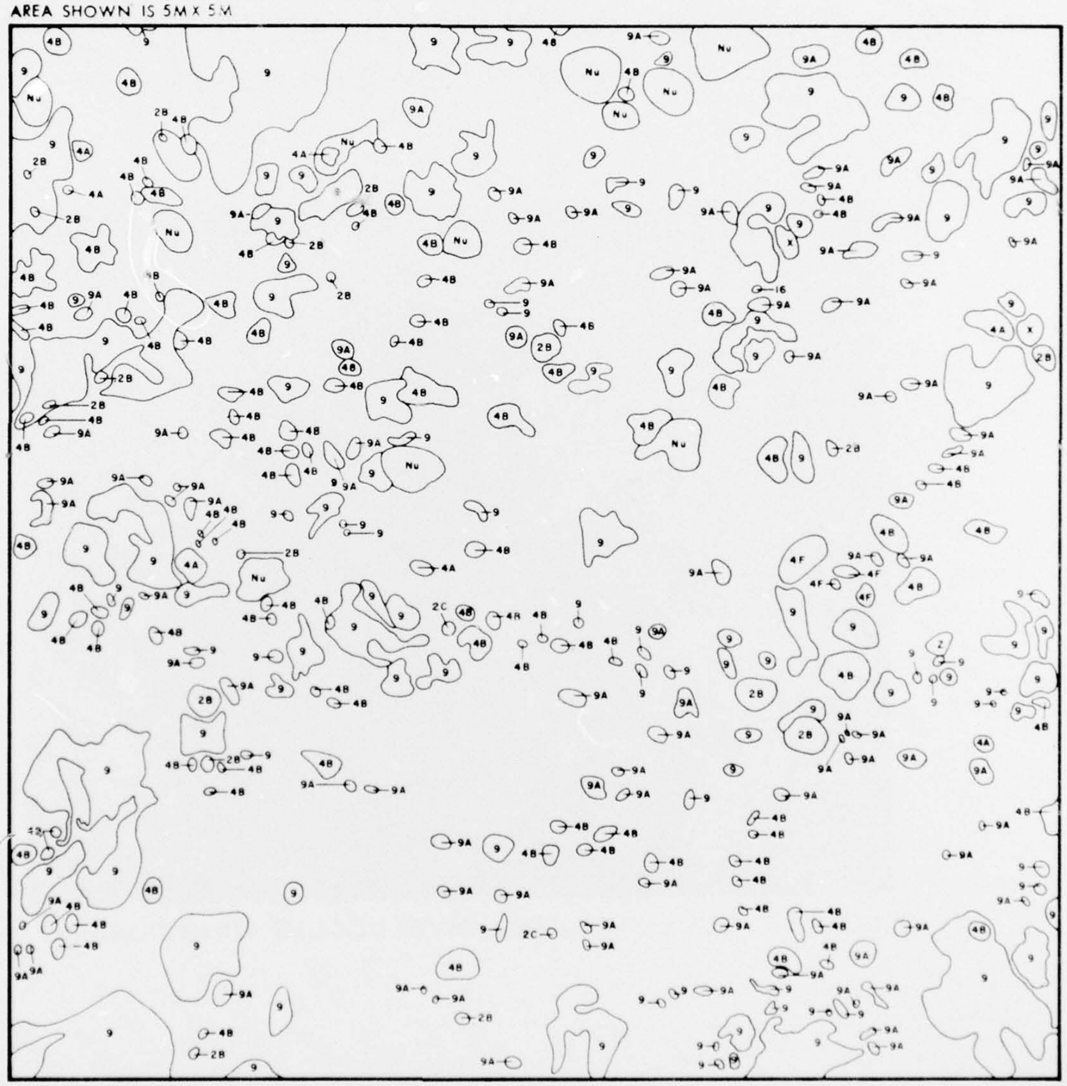
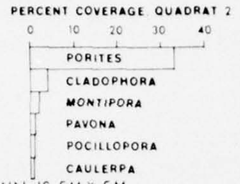


FIGURE 18. CORAL DISTRIBUTION AND ORGANISM COVERAGE, QUADRAT 1.



KEY TO QUADRAT SKETCHES

2B. P. meandrina Dana
4A. P. lobata Dana
4B. P. compressa Dana
4F. P. (Synaraea) sp. Verrill
9. Montipora sp. de Blainville
9A. M. verrucosa (Lamarck)
16. Pavona sp. Lamarck
NU. Crustose Corallinaceae

AREA SHOWN IS 5M X 5M

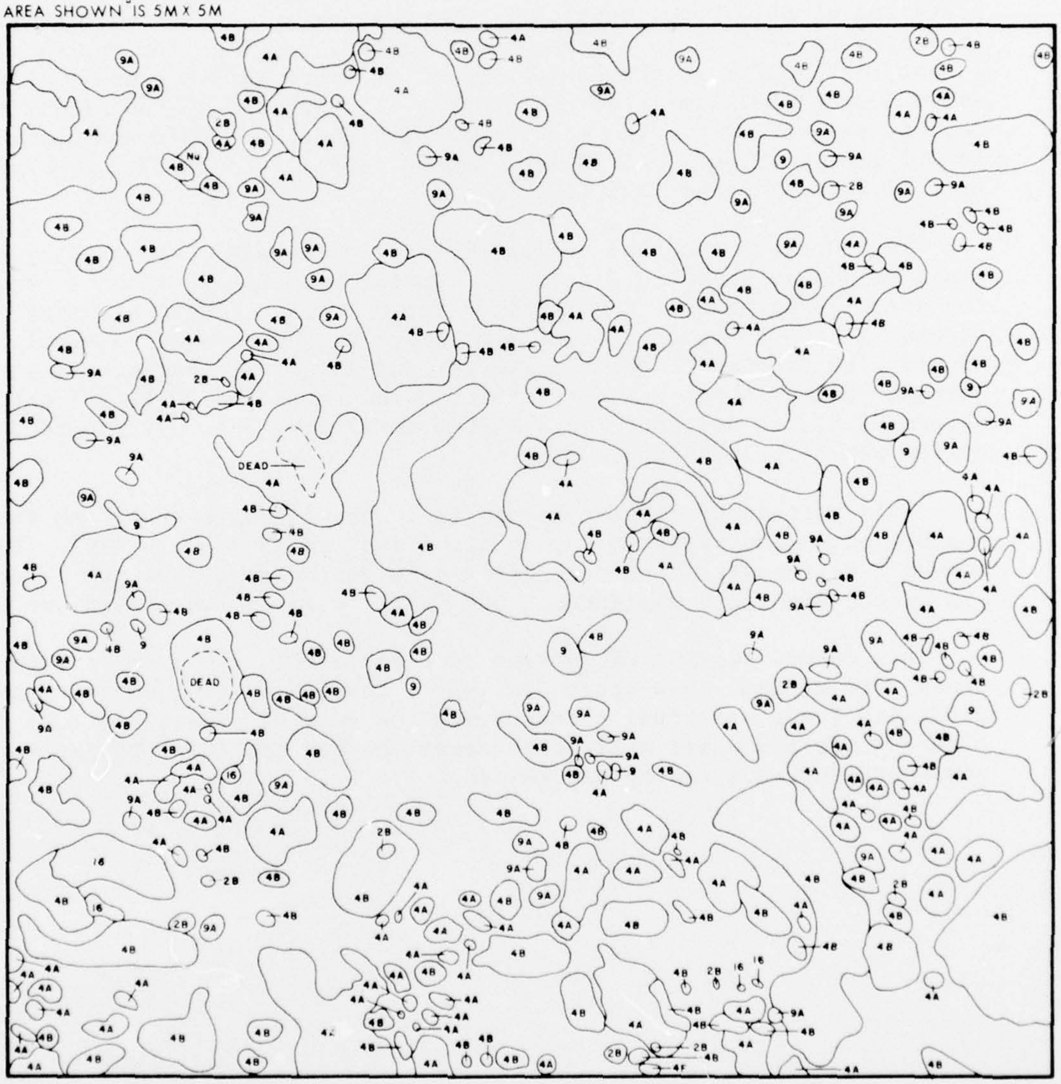


FIGURE 19. CORAL DISTRIBUTION AND ORGANISM COVERAGE, QUADRAT 2.

F. Currents

A summary of the data from the three current meters is presented in figure 20. Progressive vector diagrams (figure 21) were also constructed for each meter for selected 28-hour periods from 20 July to 22 July. These diagrams are constructed by aligning hourly current vectors so that the origin of each vector is at the end of the previous vector. A progressive vector diagram shows the path of a water particle as if it were continuously subject to the current at the meter location.

Predominant directions paralleled the depth contours as shown in the direction roses in figure 20. A weak northeasterly constant current prevailed at all three locations. Maximum current speeds were greater in deeper water than in the shallower depths, ranging from approximately 1 knot (51.5 cm/s) at the 70-foot (21.3 m) depth to 0.8 knot (41.2 cm/s) and 0.6 knot (30.9 cm/s) at the 50-foot (15.2 m) and 40-foot (12.2 m) depths, respectively. The most frequently observed speed was approximately 0.1 knot (5.1 cm/s) at 70 feet and 50 feet (21.3 and 15.2 m), and 0.15 knot (7.7 cm/s) at 40 feet (12.2 m).

The currents recorded during this period were almost entirely of tidal origin as shown in figure 21. During high tides, flow was toward the north or northeast, reversing to the opposite direction during low tides. At the 70-foot (21.3 m) depth the current changed generally within 1 to 2 hours of the tidal highs and lows. At shallower depths the current changed about an hour after the change at the 70-foot location. Speeds of 0.3 to 0.4 knot (15.4 - 20.6 cm/s) were commonly recorded during peak ebb and flood currents.

This pattern of tidal currents is in general agreement with the drogue measurements made by Laevastu, et al. (1964) on 23-24 July 1963. The drogues showed a northeasterly current off Nohili during ebb. Maximum velocities associated with this ebb current off Nohili were somewhat over one knot.

This 20-day segment of current data represents a period of light winds with minimal wave action and surf; therefore, the dominant, current-producing force was tidal. Measurement of currents during periods of higher winds and waves will be necessary before the complete pattern of nearshore currents can be determined.

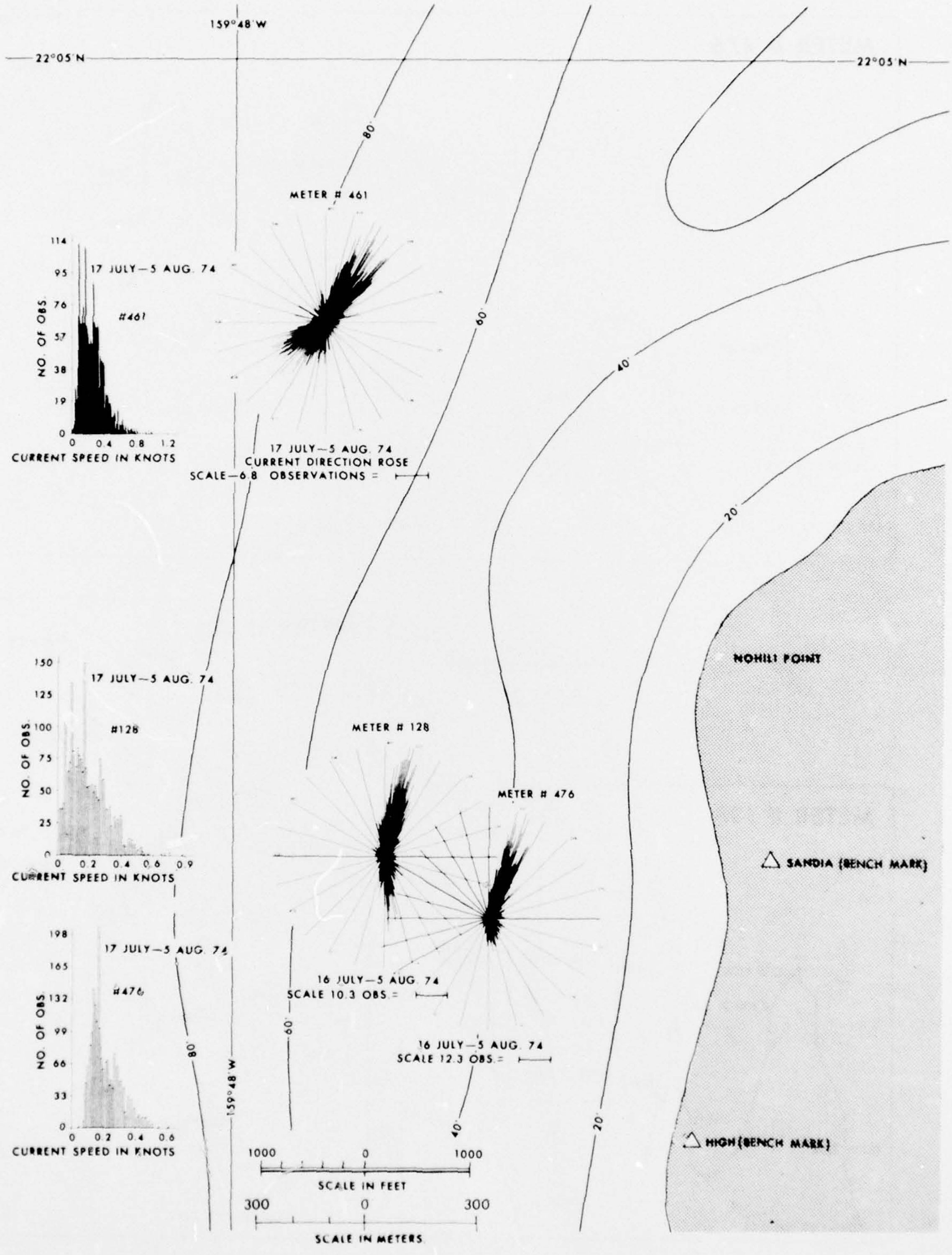


FIGURE 20. SUMMARY OF CURRENT METER DATA.

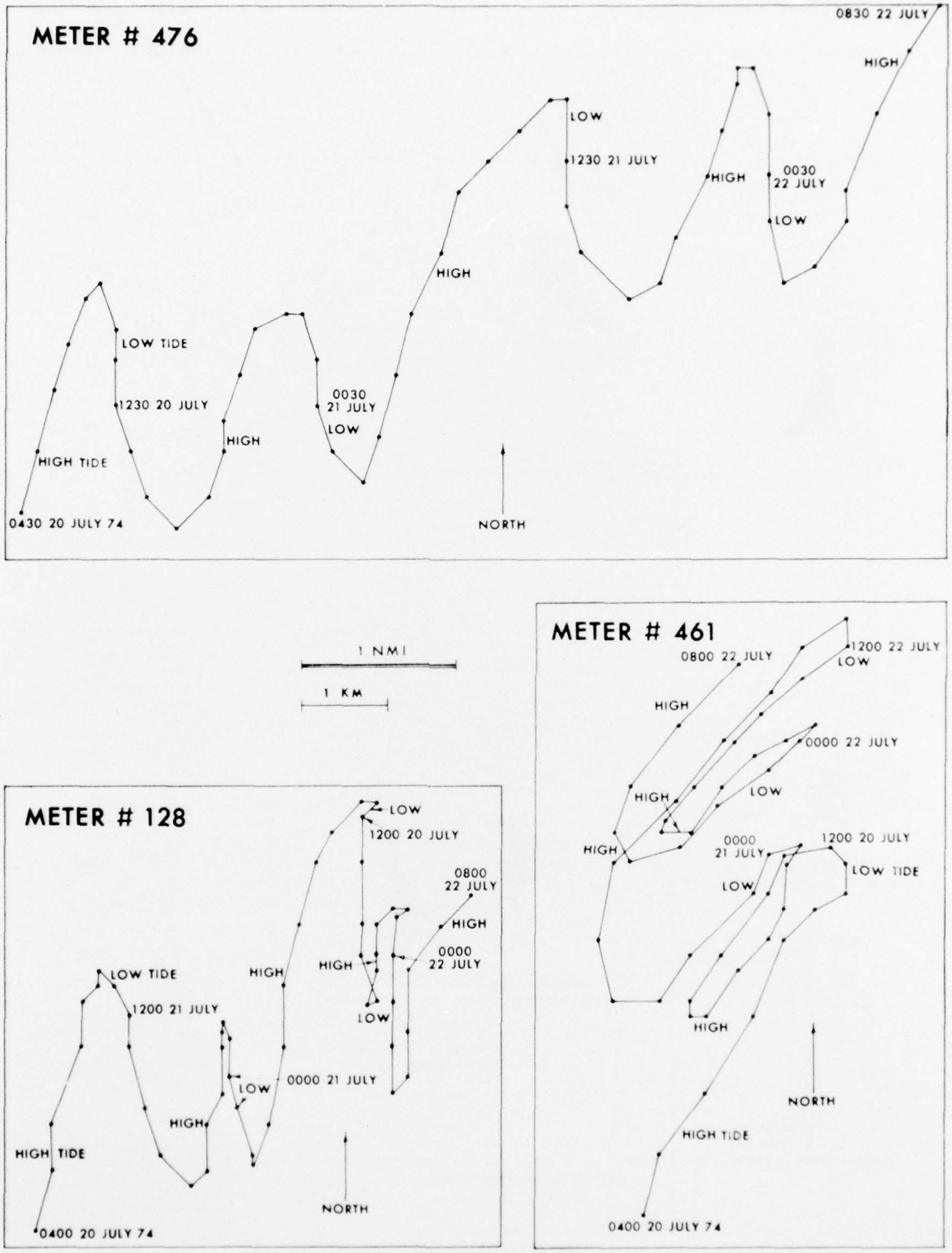


FIGURE 21. CURRENT METER DATA PROGRESSIVE VECTOR DIAGRAMS.

V. CONCLUSIONS AND RECOMMENDATIONS

1. The coastline south of Nohili Point is slowly retreating. Accelerated erosion has resulted from the cutting of a 100-foot (30.5 m)-wide gap in the beachrock formation for constructing the Nohili drainage ditch. It is recommended that no additional breaches of the beachrock be made during cable landing operations. If removal of beachrock is necessary, protective measures should be taken to prevent shoreline erosion.

2. Four vegetation zones were identified in the backshore. The vegetation plays a major role in slowing erosion by stabilizing loose sand. Precautions should be taken to assure minimal disturbance of vegetation during cable landing operations.

3. Nine beach profiles were measured and permanently marked to provide a means of monitoring beach erosion and deposition. Periodic resurvey of these profiles is recommended.

4. Three intertidal profile types were charted, each containing distinct ecological facies paralleling the coastline. The intertidal zone is highly productive in the Nohili Point area and is of economic and recreational value.

5. The marine environment and biological communities were investigated to the 70-foot (21.3 m) depth, and the ecological zones were described and charted. The coral population was restricted to three major genera typical of Hawaiian reefs. Silt-tolerant Porites dominated shallower waters, while Montipora dominated depths greater than 50 feet (15.2 m). Coral density was least in shallow water, partially because of the inhibiting effects of sedimentation from the Nohili drainage ditch runoff. A large algal population was present on the bottom at all depths. Thirty-seven families of fish were recorded, many of which have commercial or sport value. The area is moderately used by fishermen.

6. Two permanent 5-meter-square (16.4-ft-square) quadrats installed on the coral reef provide a means of monitoring changes in the sessile reef population. Periodic resurvey of these quadrats is recommended.

7. Nearshore currents during periods of light winds and low waves are predominantly tide controlled. Flow is to the south or southwest during high tide and in the opposite direction during low tide, with a weak northeasterly constant current superimposed. Current speeds of 0.3 to 0.4 knot (15.4-20.6 cm/s) are common during peak ebb and flood periods. Maximum midsummer speeds range from 0.6 to 1.0 knot (30.9-51.4 cm/s).

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The Naval Oceanographic Office, at the request of the Pacific Missile Range, initiated an environmental impact study of the effects of cable laying operations at the Pacific Missile Range Facility, Barking Sands, Kauai, Hawaii. The initial field investigation was conducted during July 1974.

Beach morphology and ecology are described, and vegetation zones are identified and charted. Beach profiles were measured and marked for future

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resurvey. Intertidal and nearshore biological communities were identified, and their distribution and densities were documented. Two permanent ecological monitoring stations (quadrats) were established to provide a means of determining changes in the coral reef populations. Three current meters were installed at locations selected by the Pacific Missile Range to assist in cable route engineering studies.